Safety Regulation Group

Civil Aviation Authority

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Hazard Analysis of the Use of GPS in Offshore Helicopter Operations

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Hazard Analysis of the Use of GPS in Offshore Helicopter Operations

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Enquiries regarding the content of this publication should be addressed to:
Safety Investigation and Data Department, Safety Regulation Group, Civil Aviation Authority, Aviation House, Gatwick Airport South, West Sussex, RH6 0YR.

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Foreword

The research reported in this paper was funded by the Safety Regulation Group of the UK Civil Aviation Authority, and was performed by Helios Technology Ltd. The work follows on from the research into the use of Differential GPS to provide guidance for helicopters approaching offshore installations reported in CAA Papers 2000/5, 2003/2 and 2003/7. In turn, this work was commissioned in response to the findings of the Helicopter Human Factors Working Group reported in CAA Paper 87007 (Recommendations 4.1.1 and 4.2.1). The Helicopter Human Factors Working Group was formed in response to Recommendation 1 of the Helicopter Airworthiness Review Panel (HARP Report - CAP 491).

En-Route Navigation

Although not directly related to offshore approaches, the hazard analysis of the use of GPS for offshore helicopter operations for en-route navigation was included to 'formalise' the situation that existed with offshore helicopter operators using GPS by default; following the closure of the Norwegian Decca chain in the late 1990's, there was no other navigation aid available when operating out of range of land-based navigation aids. The hazard analysis contained in Part 1 of this report has been used to develop an operating protocol for the use of GPS for offshore en-route navigation which has been promulgated in CAA Specification No.22. This has been implemented by the UK offshore helicopter operators.

One of the issues raised by Specification 22 is the ongoing monitoring of GPS performance which is considered to be best achieved by monitoring GPS RAIM availability. It was expected that this could be accomplished using operators' existing Helicopter Operations Monitoring Programmes (HOMP), and a study was commissioned at GE Aviation with support from Bristow Helicopters to investigate and demonstrate the practicality of this scheme. The final report for this study is included as Annex A to the main body of this report.

Since completion of the hazard analysis, two significant changes have occurred in the operating environment which will improve safety levels:

- First, the implementation of the multilateration system (a form of secondary surveillance) is well advanced with commissioning trials being carried out during late 2009. This system will allow ATC to monitor flights beyond existing radar coverage, reducing the risk of mid-air collision.
- Second, following successful in-service trials, Bristow Helicopters has committed to retrofitting TCAS II (a form of ACAS) to all of its offshore helicopter fleet. This system will provide pilots with information on proximate traffic and, in extremis, issue collision avoidance guidance commands further reducing the risk of mid-air collision.

Offshore Approaches

The unsatisfactory result of the hazard analysis of the basic JAR OPS 3 airborne radar approach (ARA) covered in Part 2 of this report is unsurprising. The main problem is that the weather radar equipment in use comprises a simplex, unmonitored system that is neither designed nor certificated for detecting obstacles, including the destination installation. Although the safety record of ARAs has been generally good, it is considered that the technology required to provide a more robust system is now available and should be pursued.

In Part 3, the use of existing GPS equipment fitted to North Sea offshore helicopters to enhance the basic ARA has been demonstrated to provide a worthwhile improvement, resulting in no hazards worse than "TOLERABLE". The modified procedure incorporating the use of existing GPS, developed and evaluated in conjunction with the UK North Sea helicopter operators, is presently being introduced. With this in place, ARAs are considered to be acceptable in the short to medium term.

Since completing the work reported in this document, further research has been conducted by Helios Technology Ltd on the development of a new approach procedure. This work formed part of the European Union 6th Framework GIANT project and comprised:

- joint UK/Norway design of a 'full' GPS approach,
- simulator trials of the 'full' GPS approach at Eurocopter,
- hazard analysis of the 'full' GPS approach,
- data collection and analysis to establish the suitability of EGNOS for the offshore helicopter application.

This work has been successfully completed. The approach procedure developed is very similar to that produced by the earlier UK CAA funded work reported in CAA Papers 2000/5, 2003/2 and 2003/7, but utilises European Geostationary Overlay Service (EGNOS) Satellite-Based Augmentation System (SBAS) rather than the VHF and MF datalink technology of the earlier work. GPS is used to provide both horizontal and vertical 'ILS look-alike' guidance. In addition, it is proposed that the procedure will utilise the marine Automatic Identification System (AIS), primarily to address the issue of detecting uncharted obstacles. The final report for this work will be published in a further CAA paper in 2010.

Further work is now in progress at Helios Technology Ltd under a European Union 7th Framework project. This project, named HEDGE (Helicopters Deploy GNSS in Europe), will develop prototype avionics and conduct demonstration flights of the the new EGNOS/SBAS guided approach procedure.

Safety Regulation Group

February 2010

Executive Summary

This document has been produced by Helios and reports on the hazard analyses performed for the Safety Regulation Group (SRG) of the Civil Aviation Authority (CAA) to support the use of GPS for offshore helicopter operations. The scope of the study covered en-route navigation and the airborne radar approach (ARA) procedures used for approaching offshore installations during conditions of low visibility.

Since the decommissioning of the Decca navigation service in the late 1990's, GPS has played an increasingly important role in supporting navigation in the North Sea region. In particular, GPS is now effectively the only navigation aid beyond the range of shore-based VOR/DME beacons. In addition, ARAs are conducted using the aircraft's weather radar which is neither designed nor certificated for the task. Earlier research [1], including flight trials, has demonstrated the potential of GPS to enhance the safety of these operations. This study has examined the hazards associated with the use of GPS for en-route navigation and for assisting ARAs.

The approach adopted for the study was to identify the key hazards, estimate their severity and probability and recommend ways to mitigate them where necessary. It should be noted that this study does not constitute a full safety case; there is no comparison with a Target Level of Safety (TLS) and, in any event, the North Sea airspace is classified as Class G for which no TLS is defined. The 'tolerability' of hazards was assessed using modified JAA AMJ 25.1309 criteria. The severity and probability of hazards are combined in a risk matrix to determine if each hazard is "UNACCEPTABLE", "TOLERABLE" or "NEGLIGIBLE". The operation is judged to be safe if all hazards are "NEGLIGIBLE"; "TOLERABLE" hazards are acceptable in the short/medium term but mitigations or a longer-term solution should be sought to reduce the hazard to "NEGLIGIBLE". Additional systems and/or procedures must be employed to reduce any "UNACCEPTABLE" hazards to no worse than "TOLERABLE".

The work was undertaken in three parts:

1 An analysis of the hazards associated with use of GPS for en-route navigation during offshore operations.

2 An analysis of the hazards associated with the existing ARA procedure.

3 An analysis of the hazards associated with a new ARA procedure which includes the use of existing North Sea helicopter GPS equipment fits.

No "UNACCEPTABLE" hazards were found for the en-route operation, but a number of new procedures were recommended to address the "TOLERABLE" hazards identified to help ensure its safety.

For the ARA procedure, three hazards were found to be "UNACCEPTABLE", which are largely a consequence of the reliance on the aircraft's weather radar.

The GPS-assisted ARA procedure reduced the "UNACCEPTABLE" hazards of the ARA procedure to "TOLERABLE", and did not introduce any new "UNACCEPTABLE" hazards. On this basis it is concluded that the new procedure represents an improvement over the existing ARA. However, the fact that most hazards remain "TOLERABLE" (not "NEGLIGIBLE") means that it is not a panacea and still has shortcomings in areas such as vertical navigation. It is recommended that work continues to address these shortcomings.

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Glossary

ACAS	Airborne Collision Avoidance System
ADELT	Automatically Deployable ELT
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIS	Automatic Identification System
ARA	Airborne Radar Approach
ASR	Air Safety Report
ATC	Air Traffic Control
ATM	Air Traffic Management
ATSE	Azimuth Total System Error
ATSU	Air Traffic Service Unit
AVAD	Automatic Voice Alerting Device
B-RNAV	Basic RNAV
CAA	Civil Aviation Authority (UK)
CDI	Course Deviation Indicator
CNS	Communications/Navigation/Surveillance
CTZ	Controlled Traffic Zone
DR	Decision Range
DR	Dead Reckoning
DME	Distance Measuring Equipment
EFIS	Enhanced Flight Information Service
EGPWS	Enhanced Ground Proximity Warning System
ELT	Emergency Locator Transmitter
FAF	Final Approach Fix
FIR	Flight Information Region
FIS	Flight Information Service
FTE	Flight Technical Error
GPS	Global Positioning System
HLO	Helicopter Landing Officer
HMR	Helicopter Main Route
HSI	Horizontal Situation Indicator
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organisation
IF	Intermediate Fix

IMC	Instrument Meteorological Conditions
IW	Intermediate Waypoint
JAA	Joint Aviation Authorities
MAPt	Missed Approach Point
MDA	Minimum Descent Altitude
MDA	Managed Danger Area
MDH	Minimum Descent Height
MOC	Minimum Obstacle Clearance
MOR	Mandatory Occurrence Report
MRAS/RIS	Modified RAS/RIS
MSA	Minimum Safe Altitude
MSL	Mean Sea Level
NATS	National Air Traffic Services
OIP	Offset Initiation Point
QNH	Barometric pressure at mean sea level
RA	(ACAS) Resolution Advisory
RAIM	(GPS) Receiver Autonomous Integrity Monitoring
RAS	Radar Advisory Service
RBE	Radar Bearing Error
RIS	Radar Information Service
RNAV	Area Navigation
RSS	Root Sum of Squares
RTSE	Range Total System Error
SAR	Search and Rescue
SD	Standard Deviation
SPS	(GPS) Standard Positioning Service
SRG	Safety Regulation Group (UK CAA)
TA	(ACAS) Traffic Advisory
TAF	Terminal Arodrome Forecast
TLS	Target Level of Safety Regulation Group
VHF	Very High Frequency
VOR	VHF Omni-Ranging

Report

1 Introduction

1.1 General

1.1.1 This document contains the hazard analyses performed to support the use of GPS for helicopter offshore operations, and has been produced for the Safety Regulation Group (SRG) of the Civil Aviation Authority (CAA) by Helios. The study addressed both en-route navigation and the airborne radar approach (ARA) procedures which are used to approach offshore installations in conditions of low visibility.

1.2 Background

1.2.1 Since the withdrawal of Decca, GPS has effectively been the only external aid to navigation available in large parts of the North Sea and has consequently been used for en-route navigation by default. Most of the airspace involved is Class G for which there are no associated navigation performance or equipment requirements. However, in view of the nature of the operations being conducted, CAA determined that the use of GPS in this role should be subject to a safety assessment to ensure that an adequate level of safety is achieved and maintained.

1.2.2 Low-visibility offshore approaches (ARAs) are based on the use of the aircraft's weather radar for guidance and as a means of detecting obstacles in the approach and overshoot paths. The use of the weather radar was borne of necessity since no other equipment was available to support these operations. Although this situation has existed for a number of years and the safety record has been reasonable, the weather radar is neither designed nor certificated for the task. The availability of GPS on offshore helicopters, however, is considered to offer the possibility to enhance the safety of these operations.

1.2.3 In view of the foregoing, CAA commissioned Helios to examine the safety implications of the use of GPS as an aid to en-route navigation and low visibility approaches to offshore installations.

1.3 Work phases

1.3.1 The work was undertaken in the following three phases:

1. An analysis of the hazards associated with the use of GPS for en-route navigation during offshore operations.
2. An analysis of the hazards associated with the existing ARA procedure.
3. An analysis of the hazards associated with a new ARA procedure which includes the use of existing North Sea helicopter GPS equipment fits.

1.3.2 The results of each phase are summarised in the following sections. The full report for each phase is then presented in Parts 1, 2 and 3 respectively.

1.4 Scope

1.4.1 This study focuses on operations in the North Sea, and the hazard assessment is specific to the operational environment in this area. The analysis performed may also be relevant to other operational areas. However, this is subject to validating the assumptions used in this report and considering the differences in the operational environment and procedures.

1.4.2 This study does not constitute a full safety case; it estimates the severity and probability of key hazards and, where necessary, recommends ways to mitigate them. Consequently there is no comparison with a Target Level of Safety (TLS) and, in any event, the airspace in question is Class G for which no TLS is defined.

1.4.3 Where risks are judged to be negligible, this is assumed to represent an adequate level of safety. The focus of the study is on what could go wrong, what the consequences could be, and what mitigations might practically be employed to minimise the risks.

1.5 Acknowledgements

1.5.1 Helios would like to thank the staff of the UK CAA, Norwegian CAA, NATS, Bristow Helicopters, Bond Offshore Helicopters and CHC Scotia Helicopters for their assistance with the work reported in this document.

2 Study approach

2.1 Introduction

2.1.1 This section describes the approach to the hazard assessment that has been applied in each part of the study. The approach taken makes use of the JAA AMJ 25.1309 criteria which, although normally applied as part of the airborne risk assessment process, is considered appropriate for assessing Air Traffic Management (ATM) risks that encompass air and ground systems. Some adjustments are made to the risk matrix as described at the end of this section.

2.1.2 It is important to note that the results of the hazard analyses contained in this report should be used as a guide and not interpreted literally. Expert judgement has inevitably been required in the analysis and there is consequently a degree of uncertainty in the figures produced. In general, the study has taken a conservative view and it is possible that a marginally 'unacceptable' risk may in fact be considered 'acceptable'.

2.2 Hazard identification

2.2.1 For each aspect of offshore helicopter operations considered, the study began with a hazard identification which established a set of 'top-level' hazards. The hazards result from human, equipment or procedural failures. The potential consequences of each of the hazards were also identified.

2.3 Conflict Scenarios analysis

2.3.1 The hazards were consolidated, eliminating duplicate and overlapping hazards, and associated with conflict scenarios. A conflict scenario represents an operational consequence of a hazard or combination of hazards.

2.4 Assess severity

2.4.1 Each conflict scenario was then assessed for its severity. The risk classification scheme used in the hazard analysis was taken from JAA AMJ 25.1309-25 [2], which is reproduced in Table 1 below.

Table 1 JAA AMJ 25.1309 severity classification

Severity	**Description**
Catastrophic	Failure conditions that would prevent continued safe flight and landing.
Hazardous	Failure conditions that would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be: A large reduction in safety margins or functional capabilities; Physical distress or higher workload such that the flight crew cannot be relied upon to perform their task accurately or completely; or, Serious injury or fatal injury to a relatively small number of the occupants.
Major	Failure conditions which would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example: A significant reduction in safety margins or functional capabilities; A significant increase in crew workload or in conditions impairing crew efficiency; or, Discomfort to occupants, possibly including injuries.
Minor	Failure conditions which would not significantly reduce aeroplane safety, and which involve crew actions that are well within their capabilities. minor failure conditions may include, for example: Slight reduction of safety margins; Slight increase in crew workload; or, Some inconvenience to occupants.

2.5 Assess probability

2.5.1 The probability classification, both quantitative and qualitative, was also based on JAA AMJ 25.1309 [2] which is presented in Table 2 below.

Table 2 JAA AMJ 25.1309 probability classification

Frequency category	**Qualitative description**	**Quantitative description**
Probable	Anticipated to occur one or more times during the entire operational life of each aeroplane.	Failure condition frequency is more than 10^{-5} per aircraft flight hour.
Remote	Unlikely to occur to each aeroplane during its total operational life but which may occur several times when considering the total operational life of a number of aeroplanes of the type.	Failure condition frequency is between 10^{-7} and 10^{-5} per aircraft flight hour.
Extremely remote	Unlikely to occur when considering the total operational life of all aeroplanes of the type, but nevertheless, has to be considered as being possible.	Failure condition frequency is between 10^{-9} and 10^{-7} per aircraft flight hour
Extremely improbable	So unlikely that they are not anticipated to occur during the entire operational life of all aeroplanes of one type.	Failure condition frequency is less than 10^{-9} per aircraft flight hour

2.5.2 The severity and probability classifications for each conflict scenario were combined to determine the corresponding risk for comparison with the JAA AMJ 25.1309 risk matrix reproduced in Table 3.

Table 3 JAA AMJ 25.1309 risk matrix

		Severity			
		Catastrophic	**Hazardous**	**Major**	**Minor**
Frequency	**Probable**	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
	Remote	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
	Extremely remote	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
	Extremely improbable	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

2.5.3 In the JAA AMJ 25.1309 assessment procedure, an operation is deemed to be safe if all the risks are negligible. "TOLERABLE" risks are acceptable subject to review and/or mitigation. If any risk is found to be "UNACCEPTABLE", then additional systems and/or procedures must be defined to reduce the risk to no worse than "TOLERABLE".

2.6 Interpretation and adjustments to AMJ 25.1309

The statistics presented in this section refer only to UK registered or operated aircraft.

2.6.1 For this study, the term "TOLERABLE" has been interpreted to mean "acceptable in the short/medium term". It is assumed that a longer-term solution will be sought to reduce the chance of any such hazards to "NEGLIGIBLE".

2.6.2 Although there is no "NEGLIGIBLE" category for catastrophic failures in AMJ 25.1309, a frequency of less than 10^{-11} per flight hour has been assumed for this.

2.6.3 The AMJ 25.1309 matrix is also ambiguous in respect of the severity to be assigned at the boundaries between the different frequency categories (i.e. 10^{-5}, 10^{-7}, 10^{-9} or 10^{-11}). Clearer boundaries have therefore been defined. The modified risk matrix is shown in Table 4.

Table 4 Adjusted risk matrix

		Severity			
		Catastrophic	**Hazardous**	**Major**	**Minor**
Frequency	**Probable** **$(f > 10^{-5})$**	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
	Remote **$(10^{-5} = > f > 10^{-7})$**	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
	Extremely remote **$(10^{-7} = > f > 10^{-9})$**	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
	Extremely improbable **$(10^{-9} = > f > 10^{-11})$**	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
	Less than extremely improbable **$(f < = 10^{-11})$**	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

3 En-route navigation

3.1 Introduction

3.1.1 This part of the work examined the hazards associated with en-route navigation for offshore helicopter operations, and focuses on GPS and RNAV-related hazards.

3.2 Hazards

3.2.1 The primary GPS/RNAV hazards presented in Table 5 were identified for en-route navigation.

Table 5 Summary of hazards

ID	Hazard
1	**Navigation database is unreliable.** For example, incorrect waypoint, route or aerodrome data. Errors can be present in the AIP or in procedures introduced by the operator.
2	**Navigation database is outdated.** Typically, this hazard can occur if the database is not updated for the current AIRAC cycle.
3	**Crew selects wrong route.** The crew may select an incorrect route from the database, or enter temporary waypoints as part of a route that are incorrect.
4	**Navigation is degraded.** There are many causes of GPS navigation degradation. Failures can occur in the space segment or in the receiver, and may be known or unknown to the crew.
5	**Loss of navigation.** This represents a total loss of the navigation function.

3.3 Conflict Scenarios

3.3.1 The following conflict scenarios were identified that could result from the hazards:

1 The helicopter flies a different route to the one intended.

2 Bad quality of aeronautical data causes deviation from the intended route.

3 Incorrect position estimation causes deviation from the intended route.

3.3.2 The conflict scenarios are linked to the hazards as shown in Table 6:

Table 6 Link between Conflict Scenarios and hazards

Ref	Description	CS1	CS2	CS3
ID1	Navigation database is unreliable		✓	
ID2	Navigation database is outdated	✓		
ID3	Crew selects wrong route	✓		
ID4	Navigation is degraded			✓
ID5	Loss of navigation			✓

3.4 Results

3.4.1 In the initial analysis, some of the conflict scenarios were found to carry an "UNACCEPTABLE" risk. The following mitigating procedures were consequently defined:

- A procedure is required to manage temporary waypoints and stop the database becoming cluttered with out-of-date information. One approach would be to delete any temporary waypoints from a previous flight before entering any new waypoints. However, since errors could be introduced when re-entering waypoints that are still needed, e.g. for semi-submersibles that have not moved, a better procedure would be to perform a check at regular intervals to clear out invalid or obsolete entries.
- A manual cross-check of each temporary waypoint against known data should be conducted (e.g. range/bearing from a known point).
- A position report to ATC should be made when joining an HMR outside of radar coverage.
- When leaving radar coverage at approximately 80 NM, the pilot should verify with ATC that the helicopter is on the correct HMR or, if flying direct, that the helicopter is proceeding on the correct track to the destination. In both cases, the heading should be recorded.
- At regular intervals the pilot should check that the heading remains stable. If VOR is available the GPS track can be cross-checked against the pre-determined VOR radial.

3.4.2 The highest severities were all caused by an un-announced deviation from the intended route. This can be caused by, for example, GPS failure, an error when programming the RNAV computer, or an error in the navigation database. It was these events that the mitigating procedures attempted to address.

3.4.3 With these procedures in place, each of the scenarios results in no worse than a "TOLERABLE" risk as shown in Table 7.

3.4.4 In addition to the procedures at 3.4.1 above, a number of additional recommendations were made for new procedures. These included monitoring and cross-checks.

3.5 Summary of procedures

3.5.1 Table 8 shows the current and proposed procedures that are recommended to mitigate against GPS and navigation failures. The foregoing analysis has assumed that 'current' actions are consistently applied by all operators, but if this is not the case then the results presented in Table 7 would be invalidated.

3.5.2 A number of the proposed procedures have been additionally labelled as "Essential". Essential procedures must be implemented in order to ensure that all risks identified in this study do not exceed "TOLERABLE" level.

Table 7 Summary of Conflict Scenarios

Conflict Scenario 1: Incorrect flight crew route selection/database checking causes deviation from intended path			
	Severity	**Probability**	**Result**
Undetected selection error leads to helicopter flying the wrong route	Within (M)RAS/RIS: A) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Conflict Scenario 2: Incorrect aeronautical data causes deviation from intended path			
	Severity	**Probability**	**Result**
The use of bad aeronautical data leads to a track deviation	Within (M)RAS/RIS: A) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Conflict Scenario 3: Incorrect position estimation causes deviation from intended path			
	Severity	**Probability**	**Result**
Case 1: RAIM unavailable (crew aware)	MINOR	REMOTE	NEGLIGBLE
Case 2: RAIM limit exceeded (crew aware)	MAJOR	REMOTE	TOLERABLE
Case 3: RAIM limit exceeded/ RAIM unavailable (crew unaware)	Within (M)RAS/RIS: A) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Case 4: Position estimate is not available	Within (M)RAS/RIS: MINOR	PROBABLE	TOLERABLE
	Within EFIS: MINOR	PROBABLE	TOLERABLE

Table 8 Summary of GPS/navigation failure mitigation procedures

Action	**Current/ Proposed**	**Comments**
Normal operation		
RAIM check pre-flight.	Current (Essential)	Required if there are 23 or fewer satellites in GPS constellation. Value to helicopter operations may be questionable since these requirements designed for fixed-wing operations.
Aircrew cross-check entry of temporary waypoints.	Current (Essential)	
Navigation database is updated each AIRAC cycle.	Current (Essential)	
CDI is set to 1 NM full scale deflection.	Current (Essential)	Impacts on navigation flight technical error. Some RNAV systems may default to 5 NM.
Regular cross-checks (e.g. fuel remaining).	Current (Essential)	Checks required every 20 minutes operators' operations manual.
Aircrew report position when in EFIS.	Current (Essential)	Report rate of 15 minutes maximum is primarily driven by SAR alerting requirements. This would only allow ATC to detect gross errors.
ATC pass information on conflicting traffic.	Current (Essential)	Separation remains aircrew responsibility.
Clear out-of-date temporary waypoints from data base at regular intervals.	Proposed (Essential)	
Aircrew cross-check all entered temporary waypoints.	Proposed (Essential)	For example, a range/bearing check against a known feature/landmark.
Aircrew verify correct heading before leaving radar coverage.	Proposed (Essential)	This applies equally to helicopter flying on an HMR or direct to the destination.
Aircrew periodically perform gross-error check that the expected heading is maintained.	Proposed (Essential)	This applies equally to helicopter flying on an HMR or direct to the destination. Where there is VOR reception, the VOR could be used to cross check against the GPS track. Note that wind can change significantly anyway, so this is only a gross-error check.
All inter-installation traffic separated vertically from HMR traffic where possible.	Proposed	Presently some inter-installation traffic flies at same altitudes as HMR traffic. It would be prudent to ensure that all inter-installation traffic remains separated from HMR traffic. It is understood that this may not be possible under certain meteorological conditions.
HOMP monitoring of RAIM if and where practical.	Proposed	Will provide quantitative data on GPS availability and enable GPS performance to be monitored.
Position report to ATC when joining an HMR outside of radar coverage.	Proposed (Essential)	To detect if helicopter has joined the wrong HMR.
Conduct monitoring of GPS navigation equipment reliability.	Proposed	Operators could maintain records of GPS receiver problems/failures.

Table 8 Summary of GPS/navigation failure mitigation procedures (Continued)

Action	Current/ Proposed	Comments
Normal operation (continued)		
Undertake regular cross-checks against alternative navigation sources (see Section 4.2.4.2) when outside VHF coverage or any other times when risks may be increased.	Proposed	
Regular review of operations.	Proposed	ATC, operators, military and CAA together to review statistics and changes in GPS, traffic levels, etc. Also opportunity to review procedures.
RAIM lost or exceeded		
Aircrew report to ATC.	Current (Essential)	Time waited before contacting ATC may not be consistent. It is proposed to standardise on, e.g. 2 mins.
ATC widens the parameters within which traffic information is passed for EFIS.	Current (Essential)	At discretion of ATC.
Cross-check against whichever other navigation sources available.	Current (Essential)	Subject to availability of alternative external navigation aids.
GPS unserviceable or navigation equipment failure		
Aircrew report to ATC.	Current (Essential)	Time waited before contacting ATC may not be consistent.
ATC widens the parameters within which traffic information is passed for EFIS.	Current (Essential)	At discretion of ATC.
Alternative navigation, e.g. DR or NDB where reception possible.	Current (Essential)	Subject to availability of alternative navigation source.
ATC procedures for wide area loss of GPS.	Proposed	ATC should have contingency procedures in the event that GPS is lost to multiple helicopters in the North Sea.
Aircrew request NDB at destination installation to be activated.	Proposed	Provides assistance in case of navigation failure.
If failure occurs on installation before take-off, inform ATC.	Proposed	Allows ATC to check the traffic density around return route is low before departure.

3.6 Miscellaneous issues

3.6.1 Introduction

3.6.1.1 During discussions with operators and NATS, several specific issues arose regarding the en-route procedures adopted in the North Sea. This section presents those issues.

3.6.2 The suitability of B-RNAV navigational accuracy

3.6.2.1 The procedures covering equipment installation, approval, operation and maintenance are the same as those for B-RNAV equipment, i.e. JAA AMJ GAI-20 ACJ 20X4.

3.6.2.2 B-RNAV navigation accuracy (5 NM 95%) appears to be insufficient for maintaining lateral separation on the HMRs. At 80 NM from Aberdeen, the HMR spacing is about 4 NM. A helicopter flying to B-RNAV accuracy could therefore be on the wrong track while still within the specified accuracy, although vertical separation would still be present. This implies that the B-RNAV standard is unsuitable for use in this airspace.

3.6.2.3 However, aircraft flying with GPS RNAV equipment are in fact expected to significantly exceed the B-RNAV navigation requirements. This is discussed in Part 1 Annex D. Hence it would be more appropriate to refer to the relevant equipment requirements etc., but not refer to 'B-RNAV' which implies a navigational accuracy of 5 NM.

3.6.3 Operator procedures

3.6.3.1 There may be some inconsistency or confusion amongst helicopter operators regarding procedures. For example, early guidance material recommended that a regular cross check of GPS position against a manual dead reckoning (DR) plot should be maintained at intervals not exceeding 15 minutes. This procedure was not mentioned by operators and in fact does not appear to be required by the CAA any more.

3.6.3.2 It may be beneficial to review all of the procedures (those currently undertaken and any new ones proposed as a result of this study) with the operators. The procedures are listed in Table 8 above.

3.6.4 Military aircraft

3.6.4.1 There are several areas of military airspace known as Managed Danger Areas (MDAs). These are above the HMR structure, with a lower altitude of 5,000 ft. However, NATS have reported that it is common practice for the military to operate both within and below the MDAs.

3.6.4.2 It is recommended that the CAA monitors this issue as it could cause a hazard to helicopters operating on the HMRs.

3.6.5 Alignment of HMRs and VOR radials

3.6.5.1 Originally, HMRs were aligned with the ADN VOR radials. However, because of a gradual shift in magnetic north, HMRs became offset from the VOR radials by about 1.5 deg. This caused confusion amongst aircrew, who often reported crossing an HMR when in fact crossing a VOR radial. To alleviate this situation, HMRs were recently re-numbered, so that each HMR is now offset by less than 0.5 degrees from the VOR radial of the same number.

3.7 HOMP monitoring of RAIM

3.7.1 A study to investigate and demonstrate the feasibility of using HOMP to monitor RAIM availability as proposed in Table 8 was commissioned at GE Aviation, working with Bristow Helicopters. The final report on this work is included at Appendix A.

3.7.2 Overall, it was not possible to demonstrate the feasibility of introducing RAIM availability monitoring on existing aircraft and GPS equipment. Although technically possible, it would involve potentially expensive modifications to the current GPS and FDR systems.

3.7.3 The introduction of multilateration and TSO-145 GPS with EGNOS/SBAS, however, is considered to mitigate against the lack of RAIM availability monitoring.

4 ARA

4.1 Introduction

4.1.1 This part of the work examined the hazards associated with the Airborne Radar Approach (ARA) procedure with the objective of identifying any weaknesses that a GPS-based procedure would need to address. The analysis therefore excludes the use of GPS in assisting an ARA.

4.1.2 The analysis also identified that there are some inconsistencies between the procedures of different operators, and it is recommended that these be harmonised. Particular areas which need to be considered include:

- Selection and use of weather/map mode on the weather radar.
- Use of autopilot.
- Training requirements, including reading and tuning the display in adverse conditions.
- Weather radar stabilisation.

4.2 Hazards

4.2.1 The primary hazards identified for the ARA are presented in Table 9.

4.3 Conflict Scenarios

4.3.1 The following conflict scenarios were identified that could result from the hazards:

1 The helicopter approaches the wrong installation.

2 The helicopter comes into conflict with the sea.

3 The helicopter comes into conflict with an obstacle.

4 The helicopter comes into conflict with the destination installation.

4.3.2 The conflict scenarios are linked to the hazards as shown in Table 10.

4.4 Results

4.4.1 The analysis concluded the tolerability of each conflict scenario to be as detailed in Table 11.

4.4.2 Three conflict scenarios are "UNACCEPTABLE". This highlights the need to improve the safety of this operation.

Table 9 Hazards

ID	Hazard
1	**Weather radar displays incorrect information.** This is a partial, unannunciated failure that may cause incorrect, incomplete or inaccurate data to be displayed.
2	**ADF displays incorrect information.** This is an unannunciated failure that results in incorrect ADF information being presented to the crew.
3	**Altimeter(s) displays incorrect information.** This is an unannunciated failure of barometric or radio altimeters that results in incorrect altimetry information being presented to the crew.
4	**Compass displays incorrect information.** This is an unannunciated failure that results in incorrect compass information being presented to the crew.
5	**Wind information wrong.** In this hazard the flight crew are provided with incorrect wind information prior to commencing the approach to the installation.
6	**Miscommunication between/with flight crew.** This hazard occurs if there is a mistake in the communication between the flight crew themselves, or between the flight crew and the installation.
7	**Flight crew error - misinterpretation of information.** This may occur if the flight crew misidentify or miss-locate the destination installation, or fail to detect or miss-locate an obstacle.
8	**Flight crew error - incorrect selection/operation of equipment.** For example the crew select the wrong mode for the weather radar or incorrectly adjust the barometric altimeter pressure setting.
9	**Flight crew error - distraction/inattention/disorientation.** For example, inadvertent drift down or up during final approach.

Table 10 Relationship between hazards and Conflict Scenarios

Ref.	Description	CS1	CS2	CS3	CS4
ID1	Weather radar displays incorrect information	✓		✓	✓
ID2	ADF displays incorrect information	✓			
ID3	Altimeter displays incorrect information		✓		
ID4	Compass displays incorrect information	✓			
ID5	Wrong wind or other information from installation				✓
ID6	Miscommunication between flight crew or between flight crew and installation	✓			
ID7	Flight crew error-misinterpretation of information	✓		✓	
ID8	Flight crew error-incorrect selection/operation of equipment	✓	✓	✓	✓
ID9	Flight crew error-distraction/inattention/disorientation	✓	✓	✓	✓

Table 11 ARA Conflict Scenario tolerability

Conflict Scenario 1: The helicopter approaches the wrong installation			
	Severity	**Probability**	**Result**
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	CATASTROPHIC	EXTREMELY REMOTE	UNACCEPTABLE
Conflict Scenario 2: The helicopter comes into conflict with the sea			
	Severity	**Probability**	**Result**
2a. The helicopter comes into conflict with the sea due to crew error.	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE	NEGLIGIBLE
2b. The helicopter comes into conflict with the sea due to altimeter failure.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
Conflict Scenario 3: The helicopter comes into conflict with another obstacle			
	Severity	**Probability**	**Result**
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
Conflict Scenario 4: The helicopter comes into conflict with the destination installation			
	Severity	**Probability**	**Result**
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	CATASTROPHIC	REMOTE	UNACCEPTABLE
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	CATASTROPHIC	EXTREMELY REMOTE	UNACCEPTABLE

5 GPS-assisted ARA

5.1 Introduction

5.1.1 This part of the study examines the hazards associated with a GPS-assisted Airborne Radar Approach (ARA). No formal procedures for GPS-assisted ARAs existed at the time this study was initiated. An early task of the study was therefore to define a procedure applicable to the use of existing North Sea helicopter GPS equipment fits through consultation with the helicopter operators and experts at the CAA. The procedure definition took into account issues such as expected workload and the capabilities of the GPS equipment.

5.1.2 The GPS-assisted ARA procedure involves the following elements:

- Selection from the area navigation system database or manual entry of the destination.
- Manual entry of the IW, as a range and bearing from the destination.
- Operation of the GPS equipment in terminal mode.
- Comparison of weather radar and GPS range and bearing data, to cross check the location of the destination.
- Use of GPS guidance (via the CDI) to guide the aircraft towards the IW.
- Use of GPS guidance (via the CDI) from the IW towards the OIP, using the CDI to establish the helicopter on the correct approach track and, hence, heading.
- Transition from GPS guidance to navigation on headings once the track is stabilised and before reaching 2.5 NM range from the destination.
- Use of GPS range and bearing to the destination during the first segment of the final approach (IW to OIP) to cross-check weather radar information (for correct 'painting' of destination and, hence, other obstacles).
- Use of GPS range to the destination to enhance confidence in the weather radar determination of arrival at OIP and MAPt.
- Use of GPS range and bearing to the destination to monitor separation from the destination. However, radar range should be used for collision avoidance since the location of the GPS reference point on the rig is not known to the crew.

5.1.3 The procedure can be modified for individual aircraft types. For example, where a suitable autopilot is available the aircraft could be flown coupled to reduce pilot workload.

5.1.4 The roles of GPS in the procedure are:

- For establishing a stable track quickly and accurately.
- As a cross-check to assist identification of the destination on the weather radar.
- To provide a range cross-check.
- To provide a bearing cross-check.

5.1.5 In the context of this procedure, the use of GPS is only considered for lateral navigation aspects. Vertical guidance will continue to be provided by barometric altimeter/radio altimeter.

5.1.6 The role of GPS assistance was assessed from two perspectives:

- Whether the use of GPS assistance introduces any new risks that are unacceptable.
- Whether the use of GPS assistance mitigates any of the hazards inherent in the ARA.

5.2 Hazards

5.2.1 The hazard identification focussed on the hazards specific to the role of GPS in the GPS-assisted approach. The primary hazards presented in Table 12 were identified.

Table 12 Hazards introduced by GPS-assistance to the ARA

ID	Hazard
1	**Navigation database is unreliable.** For example, incorrect waypoint, route or aerodrome data. Errors can be present in the AIP or in procedures introduced by the operator.
2	**Navigation database is outdated.** Typically, this hazard can occur if the database is not updated for the current AIRAC cycle.
3	**Crew selects/inputs wrong waypoint(s).** The crew may select an incorrect waypoint from the database, or enter temporary waypoints that are incorrect.
4	**Navigation is degraded.** There are many causes of GPS navigation degradation. Failures can occur in the space segment or in the receiver, and may be known or unknown to the crew.
5	**Loss of GPS navigation.** This represents a total loss of the navigation function.

5.3 Conflict Scenarios

5.3.1 Four conflict scenarios were identified that could arise from these hazards:

1a: Incorrect flight crew waypoint selection/IW entry/database checking causes deviation from intended approach path.

1b: Incorrect flight crew waypoint entry causes deviation from intended approach path.

2: Incorrect aeronautical data causes deviation from intended approach path.

3: Incorrect position estimation causes deviation from the intended approach path.

The conflict scenarios are linked to the hazards as shown in Table 13:

Table 13 Link between Conflict Scenarios and hazards

Ref.	Description	CS1a	CS1b	CS2	CS3
ID1	Navigation database is unreliable			✓	
ID2	Navigation database is outdated	✓			
ID3	Crew selects/enters wrong waypoint(s)	✓	✓		
ID4	Navigation is degraded				✓
ID5	Loss of navigation				✓

5.4 Results

5.4.1 The new procedure was found not to introduce any "UNACCEPTABLE" risks. Table 14 summarises the additional hazards and the risk tolerability of the new procedure. It can be seen that all of the new hazards are no worse than "TOLERABLE".

Table 14 New hazards and risk tolerability

Conflict Scenario 1a: Incorrect pilot waypoint selection/IW entry/database checking causes deviation from intended approach path			
	Severity	**Probability**	**Result**
A) Helicopter tries to land on unsafe installation.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
B) A conflict with another helicopter.	CATASTROPHIC	LESS THAN EX. I.	NEGLIGIBLE
Conflict Scenario 1b: Incorrect pilot waypoint entry causes deviation from intended approach path			
	Severity	**Probability**	**Result**
A) Helicopter tries to land on unsafe installation.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
B) A conflict with another helicopter.	CATASTROPHIC	LESS THAN EX. I.	NEGLIGIBLE
Conflict Scenario 2: Incorrect aeronautical data causes deviation from intended approach path			
	Severity	**Probability**	**Result**
A) Helicopter tries to land on unsafe installation.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
B) A conflict with another helicopter.	CATASTROPHIC	LESS THAN EX. I.	NEGLIGIBLE
Conflict Scenario 3: Incorrect position estimation causes the deviation from the correct approach path			
	Severity	**Probability**	**Result**
A) Helicopter tries to land on unsafe installation.	CATASTROPHIC	LESS THAN EX. I.	NEGLIGIBLE
B) A conflict with another helicopter.	CATASTROPHIC	LESS THAN EX. I.	NEGLIGIBLE

5.4.2 It was also found that the proposed GPS procedure would mitigate a number of hazards in the ARA. In particular, GPS would be effective in:

- reducing the probability of approaching the wrong installation by providing an independent cross–check of the destination location from the navigation database;
- detecting major errors in the weather radar display, such as significant inaccuracies in the displayed position of the destination (and hence other obstacles);
- assisting the pilot in initiating and maintaining an accurate track (and, hence, heading) to the destination.

5.4.3 The summary risk matrix for the GPS-assisted ARA is reproduced in Table 15. The changes resulting from the use of the modified procedure utilising GPS together with the modified procedure are underlined.

5.4.4 The consequence of adding in the GPS cross-checks is to change one CS from TOLERABLE to NEGLIGIBLE, and three CSs from UNACCEPTABLE to TOLERABLE.

Table 15 ARA procedure Conflict Scenarios updated with GPS

Conflict Scenario 1: The helicopter approaches the wrong installation			
	Severity	**Probability**	**Result**
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE	NEGLIGIBLE
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
Conflict Scenario 2: The helicopter comes into conflict with the sea			
	Severity	**Probability**	**Result**
2a. The helicopter comes into conflict with the sea due to crew error.	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE	NEGLIGIBLE
2b. The helicopter comes into conflict with the sea due to altimeter failure.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
Conflict Scenario 3: The helicopter comes into conflict with another obstacle			
	Severity	**Probability**	**Result**
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE

Table 15 ARA procedure Conflict Scenarios updated with GPS (Continued)

Conflict Scenario 4: The helicopter comes into conflict with the destination installation			
	Severity	**Probability**	**Result**
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE

6 Conclusions

6.1 Introduction

6.1.1 Given the difficult navigation environment presented by the North Sea airspace and lack of alternative aids, GPS represents an important navigation sensor for operations. This work has analysed the hazards associated with the use of GPS in offshore helicopter operations. The conclusions for each part of the study are given below.

6.1.2 The conclusions presented here represent a top level summary only. The full conclusions are given in Parts 1, 2 and 3.

6.2 Part 1: En-route operations

6.2.1 For en-route use of GPS, no "UNACCEPTABLE" hazards were identified. However, a number of operational procedures were identified to mitigate against GPS failures in this role, a number of which are considered to be mandatory, i.e. those marked "essential" in Part 1 - Table 8.

6.3 Part 2: ARA procedure

6.3.1 Three hazards associated with the ARA procedure were found to be "UNACCEPTABLE". The sources of the hazards include the weather radar and vertical guidance when flying at low altitudes.

6.4 Part 3: GPS-assisted ARA procedure

6.4.1 The GPS-assisted ARA procedure was found not to introduce any "UNACCEPTABLE" hazards. In addition, it improved all the "UNACCEPTABLE" hazards of the 'standard' ARA procedure to "TOLERABLE".

7 Recommendations

7.1 Introduction

7.1.1 This section contains the recommendations associated with all three parts of the study. The full text of the recommendations is reproduced.

7.2 Part 1: En-route operations

7.2.1 Procedures

- CAA should discuss the procedures detailed in this study with operators and NATS with a view to incorporating them into relevant manuals and training material as appropriate (see Part 1 - 6.3.1).
- CAA should discuss the mitigations proposed in Part 1 - 4.2.4.3 with operators to confirm that they are practical and acceptable. Further ideas for mitigations should also be sought from the operators.
- Operators should standardise their procedures, particularly those for contacting ATC in the event of a longer (more than a few seconds) RAIM outage (see Part 1 - 4.4.2.3).
- CAA should discuss with ATC what procedures, if any, are appropriate to cater for the event of a wide-area GPS failure (see Part 1 - 4.4.2.14 and 4.4.3.17).
- CAA and NATS should establish additional procedures for avoiding conflicts on the part of HMR 2 in the southern North Sea that is not under radar cover (see Part 1 - 4.4.5.8).

7.2.2 Monitoring

- CAA should consider creating a forum for regularly reviewing statistics and procedures with ATC, operators and the military. This would allow discussion of the performance of GPS (e.g. monitored using HOMP), the impact of changes in operations (e.g. new military areas), and to ensure that all procedures are being consistently applied.
- Operators should monitor GPS RAIM availability on a regular basis to detect any variations in GPS performance that might impact on GPS-based North Sea helicopter operations (see Part 1 - 4.4.3.16). This is consistent with ICAO recommendations and might conveniently be achieved using HOMP.

7.2.3 Investigations

- CAA should investigate the effectiveness of RAIM prediction algorithms if monitoring shows that RAIM outages in the North Sea are significant (see Part 1 - 4.4.3.16). Data from RAIM predictions should be compared to actual RAIM outages (measured by the helicopter operations monitoring programme). In the long term, RAIM prediction algorithms may have to be modified to make them more suitable for helicopter operations.
- In conjunction with operators, CAA should collect statistics on RAIM availability to validate the assumption that significant RAIM outages do not occur in the North Sea (see Part 1 - 4.4.3.1). This might conveniently be achieved through HOMP.
- The unannounced GPS receiver failure rate (integrity failure), taken as 10^{-5}, should be validated by the operators (see Part 1 - 4.4.3.9).
- NATS should establish aircraft equipment failure rates from their records in order to confirm the assumptions made in this hazard analysis (see Part 1 - 4.4.3.13).
- CAA should validate the numbers assigned to probabilities for the events listed in Part 1 - Table 7, Table 10 and Table 13.

7.3 Part 2: ARA procedure

7.3.1 Part 2 - 3.9.3 states that current ARA procedures are inconsistent between operators. This makes it harder to ensure consistent levels of safety. It is recommended that the procedures are harmonised through discussions with operators and weather radar manufacturers. Particular areas which do not appear to be sufficiently covered by existing standards include:

- Selection and use of weather/map mode on the weather radar.
- Use of autopilot.
- Training requirements, including reading and tuning the display in adverse conditions.
- Weather radar stabilisation.

7.3.2 Part 2 - 4.4.5.2 identifies that hazards in conflict scenario 2b may be mitigated by installing a second radar altimeter to provide a continuous cross-check against the first. It is recommended that this be investigated further.

7.4 Part 3: GPS-assisted ARA procedure

7.4.1 It is recommended that this procedure replaces the ARA wherever feasible.

7.4.2 The analysis has also identified the following recommendations:

- Handling and non-handling crew workload associated with the new procedure should be monitored initially to ensure that it does not, for any reason, increase significantly (see Part 3 - 2.4.5 and 2.4.6).
- The location of installation reference points on installations should be standardised (see Part 3 - 2.3.27).
- Breaches of maximum allowable discrepancy between the GPS and weather radar range and/or bearing data should be recorded for further analysis (see Part 3 - 2.3.23 and 2.3.35).

7.4.3 It is recommended that flight crew training should address the following issues:

- Even when both GPS and weather radar sensors appear to be in agreement, there is a possibility that, either both sensors are malfunctioning, or that the helicopter is approaching a different installation from the one intended (see Part 3 - 4.1.7 footnote 3).
- Crews should be made aware of the fact that current GPS reference waypoints do not necessarily indicate the location of the helideck (as might be expected) (see Part 3 - 2.3.27).

7.4.4 Crews should be made aware of the initial lack of confidence likely in the track and heading established under GPS guidance, and consideration should be given to conducting 'practice' ARAs in good weather to build up experience with the approach procedure in benign conditions (see Part 3 - 2.5.1).

8 References

[1] CAA Papers 2000/5, "DGPS Guidance for Helicopter Approaches to Offshore Platforms", 2003/02, "DGPS Guidance for Helicopter Approaches to Offshore Platforms - Follow-on Studies", and 2003/07 “Effect of Helicopter Rotors on GPS Reception”.

[2] JAA, System Design and Analysis, Change 14 Joint Aviation Authorities Doc. JAR-25, Section 3: Advisory Material Joint, Doc. AMJ25.1309, including Change 15, 1 October 2000.

Appendix A Use of HOMP to Monitor GPS RAIM Availability

This appendix contains an unabridged copy of the above report.

Feasibility Assessment of the Use of HOMP to Monitor GPS RAIM Availability

(CAA Contract No 967)

REP1782(1)

October 2009

GE AVIATION
School Lane Chandlers Ford
Eastleigh Hampshire SO53 4YG
United Kingdom

CONTENTS **Page Number**

GLOSSARY

ARINC	Aeronautical Radio, Inc.
ATC	Air Traffic Control
BAFDA	British Airways Flight Data Analysis
CAA	Civil Aviation Authority
CMC	Canadian Marconi
DAPU	Data Acquisition and Processing Unit
DDP	Declaration of Design and Performance
DGPS	Differential Global Positioning System
DIP	Dual In-line Package
EGNOS	European Geostationary Navigation Overlay Service
EMC	Electromagnetic Compatibility
FDAU	Flight Data Acquisition Unit
FDR	Flight Data Recorder
FMS	Flight Management System
GPS	Global Positioning System
HIL	Horizontal Integrity Limit
HOMP	Helicopter Operations Monitoring Programme
HSI	Horizontal Situation Indicator
ICAO	International Civil Aviation Organisation
IHUMS	Integrated Health & Usage Monitoring System
NCD	No Computed Data
PCB	Printed Circuit Board

QAR	Quick Access Recorder
RAIM	Receiver Autonomous Integrity Monitoring
RTCA	Radio Technical Commission for Aeronautics
SBAS	Satellite Based Augmentation System
SDI	Source/Destination Identifiers
SSM	Sign/Status Matrix
YED	Yeovil Electronics Developments Ltd

1 INTRODUCTION

The CAA has been formalising the use of GPS for helicopter operations in the North Sea, including en-route navigation and offshore approaches. Although GPS accuracy is not an issue, there must also be an acceptable level of availability of the integrity assured GPS position solution (which may be annunciated via a 'RAIM available' indication). There is limited information on the actual level of availability currently being achieved, and the CAA may require operators to monitor GPS availability as part of the formalisation process. In support of its initiative on the use of GPS, the CAA issued a contract (no. 967) to GE Aviation (formerly Smiths Aerospace) with Bristow Helicopters as its subcontractor, for a project to investigate the feasibility of monitoring GPS RAIM availability within Bristow's Helicopter Operations Monitoring Programme (HOMP). The feasibility assessment considered the following two elements:

- Determine how Bristow's current HOMP system could be modified to incorporate routine monitoring of GPS RAIM availability.

- Investigate the feasibility of routinely recording and downloading GPS RAIM availability data from Bristow's North Sea fleet of AS332L helicopters.

If the result of the feasibility assessment was positive, the intent was to implement the monitoring of GPS RAIM availability in a limited in-service trial. However, the assessment did not demonstrate the feasibility of RAIM availability monitoring, therefore the project was terminated and the findings summarised in this report.

Section 2 provides the background to the interest in RAIM availability monitoring. Section 3 considers the incorporation of RAIM availability monitoring into Bristow's current HOMP system, while Section 4 assesses the feasibility of the on-aircraft recording of GPS RAIM availability on an existing aircraft. Section 5 discusses the outcome of the feasibility assessment, and also other recent, relevant developments. Finally, Section 6 presents some brief conclusions and recommendations.

2 BACKGROUND

The CAA has been investigating the use of GPS for helicopter operations in the North Sea, including en-route navigation and offshore approaches. An alternative navigation aid was required for en-route navigation following closure of the Norwegian Decca chain in 1997, and GPS presented a readily available solution. Low visibility offshore approaches have been conducted using the aircraft's weather radar which is neither designed nor certified for the task; although service experience has generally been good, its continued use in the medium to long term was not considered to be acceptable. Following a brief and unsuccessful attempt to develop an approach radar, differential GPS (DGPS) was identified as a potential candidate.

Flight trials of differential DGPS guidance for conducting offshore approaches were performed during the mid-1990s [1]. Although very successful, preliminary analysis of the trials results established that not all expected satellites were being 'seen' by the GPS receiver. Further investigation showed that this was due to the effect of the helicopter's rotors on GPS signals passing through them which was analysed in greater detail and confirmed in a subsequent trial [2]. Although this phenomenon did not cause any significant problems during the trial, the overall effect was a reduction in the number of satellites available to the helicopter's GPS receiver which would be present during en-route operations as well as while conducting offshore approaches.

The limited overall effect of the loss of satellite signals 'seen' during the offshore approach trials was due to the redundancy in the GPS space segment, i.e. an aircraft can usually 'see' more satellites than it actually needs to generate a position solution. It is a fact, however, that many of the satellites in the GPS constellation are operating well beyond their design lives and some are only one failure away from complete collapse – see Figure 2-1.

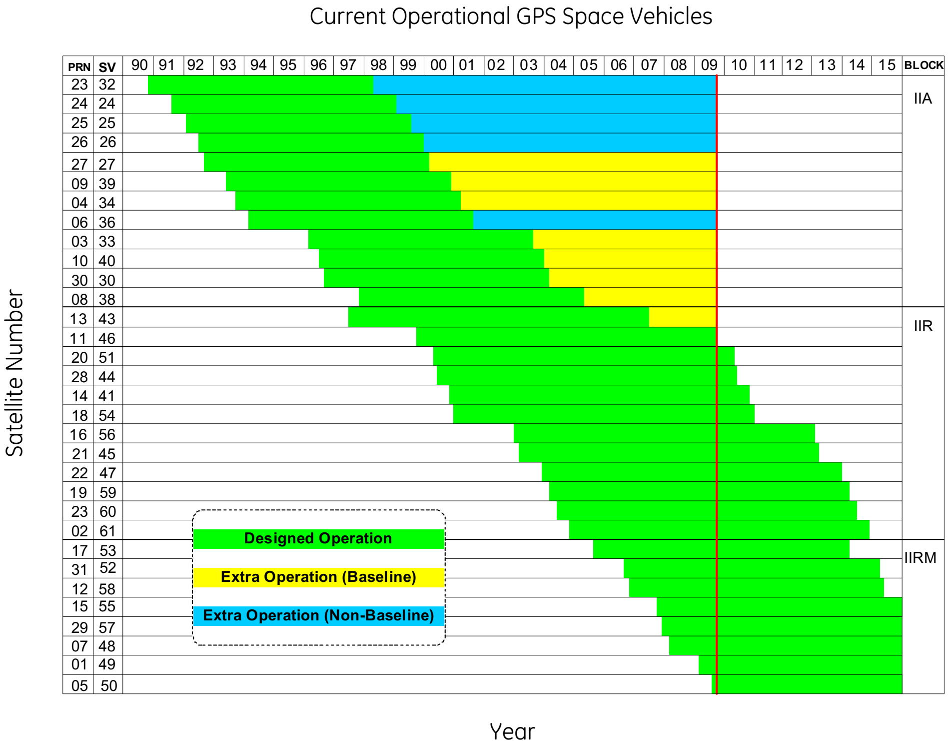

Figure 2-1: Status of GPS Constellation as at 30 September 2009 (Design vs Actual Life)

While service experience has shown constellation reliability to be generally good, satellite failure (or indeed planned satellite outages for maintenance) was considered to be a factor that needed to be accounted for.

Since the impact of satellite failures could not be exercised during the offshore approach trials, the trials results were 'extrapolated' using computer simulation. This work, reported in [3], clearly demonstrated a significant effect of satellite failures on the availability of a position solution; no significant effect on accuracy was found. It was therefore concluded that the key system performance parameter for helicopter-mounted GPS was availability.

System availability means availability of an integrity assured position solution. For DGPS as proposed for conducting offshore approaches, integrity is provided via the differential corrections. For 'stand-alone' (i.e. unaided or non-differential) GPS as used for en-route navigation however, integrity is normally assured using a technique known as receiver autonomous integrity monitoring (RAIM). Depending on the technique employed, this requires the GPS receiver to be able to 'see' either one or two satellites more than would be required simply to provide a position fix. Hence the first indication of loss of system performance, due to the effects of the helicopter's rotors and/or through satellite failures (or planned outages for maintenance), would be the loss of RAIM.

In summary, due to the less than ideal reception of GPS signals on helicopters and the general state of the GPS satellite constellation, there is definite need to monitor system performance. Since the key helicopter-mounted GPS performance parameter is system availability and since this is reflected in RAIM availability, it follows that the best way of monitoring overall system performance is to monitor the availability of RAIM.It should also be noted that, in addition to the afore-mentioned need, ICAO recommends that GPS data be monitored and recorded primarily to assist accident investigation (see para. 2.4.3.1 of [4]). Although GPS signals are monitored and recorded at fixed onshore sites in the UK, due to the complexity of the characteristics of GPS reception on helicopters, it would be very difficult to translate such data into the actual performance experienced by the helicopter. RAIM availability monitoring could help to address this issue.

For all of the above reasons, RAIM availability monitoring is recommended in Section 3.2 of [5], the document which formalises the use of GPS for en-route navigation during offshore operations.

3 FEASIBILITY ASSESSMENT OF THE EXPANSION OF HOMP TO INCLUDE A NEW MONITORING REQUIREMENT

HOMP (or Flight Data Monitoring) systems are now being used by all helicopter operators providing offshore support to the UK oil and gas industry. HOMP involves the pro-active use of flight data to identify and address operational risks before they can lead to incidents and accidents [6] [7]. Systems typically perform two types of analysis:

- Event analysis - detects pre-defined operational events and provides information on occurrences which may increase operating risks.
- Measurement analysis - takes a set of measurements on every flight and provides information on the whole operation (i.e. it quantifies normality).

The systems are designed to be user configurable so that operators can tailor the monitoring performed to their own standard operating procedures.

Using the HOMP system currently in service with Bristow Helicopters as an example, the feasibility of implementing new events and measurements to monitor GPS RAIM availability was demonstrated. This system comprises a helicopter version of the British Airways Flight Data Analysis (BAFDA) system. The following section specifies example new events and measurements that could be implemented with the existing HOMP system functionality for monitoring of GPS RAIM availability.

3.1 Example New HOMP Events and Measurements for GPS RAIM Availability Monitoring

3.1.1 Event Analysis

Two variations of a GPS RAIM loss event could be implemented, with different duration thresholds. These thresholds would be configurable, and could be adjusted on the basis of in-service experience. As an example, the events may initially have RAIM loss detection durations of 10 seconds and 1 minute. In addition, the events could be separately applied in the flight phases of take-off, cruise, and landing. In this way, in addition to recording latitude and longitude at the time of an event, the take-off and landing events would be automatically associated with a specific location.

For the above example, a total of six new HOMP events would be implemented:

GPS RAIM loss > 10 seconds during take-off
GPS RAIM loss > 1 minute during take-off
GPS RAIM loss > 10 seconds during cruise
GPS RAIM loss > 1 minute during cruise
GPS RAIM loss > 10 seconds during landing
GPS RAIM loss > 1 minute during landing

It is useful to store the values of some flight data parameters in an event record to provide information on the aircraft state at the time an event is triggered. In particular, this data could be used to determine the paths of the GPS satellite signals relative to the airframe which could help to explain any outages (airframe masking, effects of rotors). If the frequency or duration of outages is considered excessive, then this data could be used to help develop a solution, e.g. re-siting of the GPS antenna. For example, the following parameters could be recorded:

- Latitude
- Longitude
- Pitch
- Roll
- Heading
- Altitude

3.1.2 Measurement Analysis

Two types of measurement could be implemented. The first would record the number of GPS RAIM loss occurrences, and the second would record the duration of each RAIM loss. Again, individual measurements can be implemented for the take-off, cruise and landing flight phases of each flight to provide more location-specific information.

The measurements would be stored with all the other currently available measurements and documentary data enabling the identification of a specific aircraft and flight. This data could then be used to generate histograms of the type shown in Figure 3-1, for example, to characterise the RAIM outages in terms of frequency and duration. Short outages of a few seconds are not significant as the aircraft is unlikely to deviate from its intended flight path, but could be a nuisance if they occurred too frequently. Longer outages could be more serious as there is more scope for navigation errors.

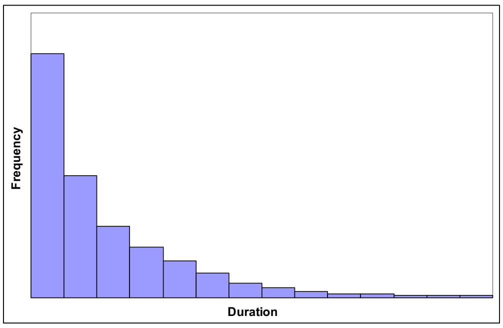

Figure 3-1: Frequency vs Duration Histogram

4 FEASIBILITY ASSESSMENT OF THE ON-AIRCRAFT RECORDING OF GPS RAIM AVAILABILITY ON AN EXISTING AIRCRAFT

An exercise was carried out to demonstrate the feasibility of recording GPS RAIM availability from the FreeFlight 2101 GPS installed on Bristow's IHUMS equipped AS332Ls. There were two elements to this feasibility assessment, which are described in the following two sections.

4.1 Recording and Routine Download of GPS RAIM Availability Information

The GPS RAIM availability information would need to be recorded on the aircraft and then routinely downloaded for analysis. To demonstrate feasibility, it should be possible to use the mechanism that has already been implemented for the routine downloading of flight data for the HOMP analysis. The standard solution has been to fit a Quick Access Recorder (QAR) to record a copy of the data sent to the aircraft's Flight Data Recorder (FDR). Some QARs can include an additional signal acquisition capability to allow the recording of parameters that are not currently stored on the FDR, however this capability is not a standard feature. Therefore, to demonstrate recording and download feasibility it should ideally be possible to add the GPS RAIM availability information to the existing FDR data frame. As many FDR data frames already have a full complement of parameters, the most feasible way to do this would be to record the information as a physical discrete. However, even modifying a data frame to accept an additional discrete can be costly as a retrofit to an aircraft manufacturer-supplied FDR system may be required.

Reviewing the IHUMS documentation for Bristow's AS332L aircraft revealed that the discrete word slots in the FDR data frame are currently fully populated. Therefore it would be necessary to remove an existing discrete to enable GPS RAIM availability to be recorded. Bristow reviewed the existing non-mandatory discretes in the data frame and determined that one of the three inner, middle and outer marker beacon discretes that are currently recorded could be removed and replaced by a RAIM availability discrete. It would also be necessary to update the relevant FDR documentation. It was considered that the feasibility of the recording and routine download of GPS RAIM availability information had been demonstrated, provided that it was in the form of a discrete parameter.

4.2 Acquisition of GPS RAIM Availability Information

The final part of the assessment was to establish the feasibility of obtaining an output from the aircraft's GPS which provided the required RAIM availability information. The investigation was carried out on Bristow's AS332L aircraft, which are equipped with the FreeFlight 2101 GPS.

An investigation was performed to determine whether the FreeFlight GPS provides a RAIM available output, and also the nature of any output (e.g. a physical discrete, or a parameter on an ARINC 429 bus). FreeFlight Systems was contacted, and reported that the 2101 does not provide a physical discrete output for RAIM. However, it was stated that a RAIM status output is available on the ARINC 429 bus. The relevant output was identified as a “RAIM Integrity Alert” discrete contained in ARINC 429 Label 261, which provides GPS status information.

The GPS “Nav valid flag” that is output to an external HSI was investigated as a possible alternative source of information on RAIM availability. Unfortunately FreeFlight Systems stated that a loss of RAIM would not necessarily set this flag to an invalid condition and the GPS could display a Nav valid signal but not have RAIM. By manually deselecting satellites, Bristow performed a practical demonstration to confirm that the Nav valid flag is not set to an invalid condition when RAIM is lost.

It was therefore determined that the only way to establish RAIM availability would be to monitor the RAIM status output discrete on the ARINC 429 bus. Possible solutions identified were to modify the IHUMS DAPU software to extract the RAIM status output from the ARINC 429 data, or install an ARINC 429-to-relay output converter to convert the RAIM status output to a physical discrete, and then for the DAPU to record this as a discrete input. For the purposes of a feasibility demonstration this latter option was considered to be the most practical solution, and was investigated further.

4.2.1 *ARINC 429 to Relay Output Converter*

A suitable converter device was sourced from Yeovil Electronics Developments Ltd (YED). This is the “ARINC 429 to Relay Output” converter shown in Figure 4-1 (part number YED/429/R1/VF).

This converter can extract a specific ARINC 429 parameter from a user selectable Label and translate it into a switched discrete output. The Label, SDI, SSM, and Parity are selected via DIP switches on the PCB. The "controlling bit" within the selected ARINC Label (in this case the RAIM status bit) used to control the state of the relay can be selected via a 5-bit Binary coded DIP switch on the PCB, for example selecting "10011" will cause bit-19 in the selected Label to activate the relay. Bits in the range 9 to 31 are selectable. For a continuously varying parameter, it is necessary to specify the range and limits of the required parameter that will switch the relay discrete output. For example, an ARINC 429 label containing "Ground Speed" could be programmed such that when this parameter drops to a predefined value the relay discrete is switched.

Figure 4-1: ARINC 429 to Relay Output Converter

The unit is powered from an external 28 VDC (18-36V) nominal supply. The inputs are opto-coupled for electrical isolation purposes and are also reverse polarity protected. The connections for the YED/429/R1/VF1 converter are via a D9 filtered plug. The weight and dimensions of the unit are as follows:

- Weight: Approx. 300 grams
- Length including flanges: 140.0 mm
- Length excluding flanges: 114.0 mm
- Width: 64.0 mm
- Height: 30.0 mm

One converter unit was obtained for installation on a Bristow AS332L. Bristow's Design Office took responsibility for designing the aircraft installation, and also issuing a Declaration of Design and Performance (DDP) to allow the unit to be fitted to an aircraft. After reviewing the limited documentation available, it was determined that the unit was safe to install on an aircraft if it was potted in epoxy prior to installation, and a test certificate could be provided to show that the unit passed the following minimum set of electromagnetic compatibility (EMC) tests:

RTCA-DO160C Part 15 CSD Cat A Compass Safe Distance
RTCA-DO160C Part 16 Cat Z Power Input
RTCA-DO160C Part 17 Cat B Voltage Spike
RTCA-DO160C Part 18 Cat B Audio Frequency Conducted Susceptibility
RTCA-DO160D Part 20 Cat S Radiated Immunity

The ARINC 429 to relay converter was subjected to the above EMC testing, and passed all the tests. Bristow then installed the unit in an AS332L aircraft undergoing heavy maintenance.

4.2.2 Testing of ARINC 429 to Relay Output Converter and FreeFlight 2101 GPS

Testing of the completed installation showed that GPS RAIM availability was not being recorded on the aircraft. The ARINC 429 to relay converter's DIP switches that select the appropriate label and bit were checked, and it was confirmed that these were set correctly. Bristow then removed the unit and bench tested this by connecting it to a FreeFlight 2101 GPS that was kept in Flight Planning for training purposes. Again no output could be obtained from the ARINC 429 to relay converter to indicate a loss of RAIM availability.

The ARINC 429 to relay converter was sent back to YED for further testing. YED confirmed that this was functioning correctly, and returned the unit to Bristow. Again, bench testing at Bristow failed to obtain any output from the ARINC 429 to relay converter related to a loss of GPS RAIM availability.

Bristow then obtained an ARINC 429 bus analyser to check all the bits in the ARINC 429 Label 261 (GPS status) output from the FreeFlight 2101 GPS. It was found that none of the bits changed state when the GPS was forced to "RAIM unavailable" by deselecting satellites. As a final check, Bristow reviewed the FreeFlight installation manual detailing all the inputs and outputs, and tested ARINC 429 Labels 261, 270, 271, and 275 to determine whether any bits changed when RAIM was unavailable. No bits changed in the testing, and no outputs were found that could indicate the number of satellites in view.

FreeFlight was contacted again, and a FreeFlight engineer reviewed the software code to obtain definitive information on the ARINC 429 output. It was confirmed that the bits in Label 261 could only indicate when a satellite had failed, and not whether there were enough satellites in view. Having initially reported that a "RAIM unavailable" flag was included in the ARINC 429 output, FreeFlight finally stated that there were no labels in the output that could provide this information. The confusion is believed to have been partly due to a change in personnel since Trimble, the original developer of the GPS, had been bought by FreeFlight. This occurrence is not unique, and GE Aviation is aware of other flight data recording applications where it was found that information believed to be available on an aircraft according to the documentation was not actually present, resulting in the need for modifications to the flight data acquisition system.

During the course of the study, the version of software in the FreeFlight 2101 GPS on all Bristow's European aircraft was updated from 241D to 241J. The updated software included a Horizontal Integrity Limit (HIL) word (Label 130) in the ARINC 743 output. FreeFlight was contacted to see if there were any bits in this word that could indicate RAIM availability, but the response was again negative.

This part of the assessment produced a negative result, in that it was not possible to demonstrate the feasibility of recording RAIM availability on Bristow's AS332L helicopters equipped with the FreeFlight 2101 GPS. To do so would require FreeFlight to modify the GPS software to output the required information.

4.2.3 Investigation into the use of an Alternative GPS

As a final task in the feasibility study, Bristow investigated the availability of a RAIM output from the Canadian Marconi (CMC) CMA3012 GPS receiver, which is integrated into the CMA3000 FMS, on its fleet of EC225 aircraft. CMC was contacted to find out whether the CMA3012 (or CMA3000) outputs any signal to indicate that RAIM is not available due to insufficient satellites in view. CMC reported that the required information is provided on GPS output ARINC Label 130 HIL. Whenever RAIM is available, the SSM (Sign/Status Matrix) bits are set to “Valid”, otherwise the SSM is set to “Test” while the unit is in test, “NCD” if RAIM is not available (insufficient satellites), or “Fail” if failed. YED was contacted to determine if it would be possible to use the existing ARINC 429-to-relay converter to trigger the relay from the SSM bits. It was confirmed that this could be done, although it may require re-programming of the unit’s EPROM.

However, having previously been misled by documentation, before progressing further it was considered that it would be prudent to conduct a test to verify that the SSM bits of Label 130 do change when RAIM availability is lost. Unfortunately the CMA3012 is a blind box with no user interface and, even if it were possible to tap into the databus on the aircraft with the CMA3000 FMS connected, there was no user interface that would allow satellites to be deselected. The only way to reduce the number of satellites would be to physically mask the aerial, and with the satellites continuously moving this was not considered to be a practical proposition. Bristow was therefore unable to conduct a test to confirm the presence of the required RAIM availability output on the EC225.

A second concern was the potential difficulty and cost of adding a new parameter to the Flight Data Acquisition Unit (FDAU) on the EC225, as there is no current discrete parameter that could be substituted without the agreement of Eurocopter's Design Department.

5 DISCUSSION ON THE OUTCOME OF THE FEASIBILITY ASSESSMENT AND OTHER RELATED DEVELOPMENTS

In this relatively small scale project it was not possible to demonstrate the feasibility of monitoring GPS RAIM availability. On Bristow’s AS332Ls it would need a modification to the FDR data frame which, in this case, is feasible because of Bristow’s historical involvement in the development of the IHUM system. It would also require a software modification to the FreeFlight 2101 GPS to provide a RAIM availability output, which was beyond the scope of the project. Considering an alternative aircraft, the EC225, other issues were identified. While the documentation indicated that GPS RAIM availability information should be available, owing to the integrated nature of the aircraft's FMS, it was not possible to test this. Recording the information would also require the involvement of Eurocopter's Design Department, and possibly a modification to the aircraft's FDAU. Again, this was considered to be beyond the scope of the project.

Without RAIM availability monitoring, overall system performance can only be monitored through pilot feedback; pilots receive a warning on the flight deck when RAIM is unavailable. Experience indicates that, although there are other types of GPS failure, RAIM unavailable messages do not occur in cruising flight, and the only time that these messages are triggered is on the ground/helideck due to masking of GPS signals by obstructions. This situation could change as there is a risk that the GPS system will degrade in the future as satellites age, but crew reports should identify if and when that happens. However, there is a concern that relying on crew reports may result in the under-reporting of RAIM availability issues. For example, short duration outages that may be indicative of marginal system performance and the onset of more significant degradation may go unnoticed during periods of high crew workload. In addition, there would not be correlated FDR data (position, attitude, altitude) that might provide an understanding of the reason for an outage. Furthermore, pilot monitoring cannot necessarily be relied upon for fulfilling the intent of the ICAO recommendation for performance monitoring in respect of accident investigation; the crew may be unable to accurately recall details or may have perished in the accident.

However, consideration needs to be given to other developments that have occurred since the start of this GPS RAIM monitoring project. In the North Sea, a multilateration system is being introduced that allows Air Traffic Control (ATC) to provide a radar-like service over a very high proportion of the current North Sea operating area. ATC will use this service to monitor aircraft tracks, and will contact any aircraft that are off track. This will reduce the importance of GPS RAIM monitoring. The introduction of TSO-145 certified GPS systems with EGNOS (European Geostationary Navigation Overlay Service)/SBAS (Satellite Based Augmentation System) introduces an additional ranging signal from the geostationary satellite, making the loss of RAIM less likely. EGNOS/SBAS will also supplement the GPS systems by independently monitoring the reliability and accuracy of the signals, reducing or eliminating the need for RAIM. EGNOS/SBAS is being proposed to fulfil the role of offshore approach guidance and, once available, can also be used for en-route navigation. With EGNOS/SBAS in place the need for RAIM availability monitoring will be significantly reduced.

Notwithstanding the foregoing, the desirability of monitoring GPS performance should be borne in mind for future avionic developments when the required functionality could readily be incorporated.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

An investigation has been performed to determine the feasibility of the routine monitoring of GPS RAIM availability status on Bristow's North Sea fleet of AS332L helicopters. The additional monitoring requirement could be readily incorporated into Bristow's existing HOMP system. It would also be possible to record a GPS RAIM availability output as a discrete on the aircraft's FDR, first converting information into a suitable discrete, if necessary. However, despite documentary information indicating the contrary, it was found that the FreeFlight 2101 GPS fitted to Bristow's AS332Ls does not output RAIM availability. The GPS software would need to be modified to obtain the required information, and this was beyond the scope of the project.

Bristow's EC225s were considered as an alternative vehicle for the feasibility assessment, but the investigation of this aircraft raised other issues. While the documentation indicated that GPS RAIM availability information should be available, owing to the integrated nature of the aircraft's FMS it was not possible to test this. Recording the information would also require the involvement of Eurocopter's Design Department, and possibly a modification to the aircraft's FDAU. Again, this was beyond the scope of the project.

It has not been possible to demonstrate the feasibility of introducing RAIM availability monitoring on existing aircraft and GPS systems. While it is technically possible, it would involve potentially costly modifications to the current GPS and FDR systems.

Recent developments such as multilateration and TSO-145 GPS with EGNOS/SBAS reduce, and could ultimately eliminate, the need for RAIM availability monitoring. Therefore, although the RAIM availability monitoring feasibility investigation has produced a negative result, the consequences of this are being mitigated by other developments.

6.2 Recommendations

For existing aircraft and GPS systems, consideration should be given to formalising the pilot reporting of occurrences of loss of RAIM availability.

When developing a specification for the next generation of GPS systems for use on offshore approaches, requirements for the output and recording of integrity information should be fully considered.

Similarly, consideration should be given to including the provision for appropriate GPS performance data in the FDR data frame for accident investigation and any future performance monitoring considered appropriate.

7 REFERENCES

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[6] Final Report on the Helicopter Operations Monitoring Programme (HOMP) Trial, CAA Paper 2002/02, CAA, London, September 2002.

[7] Final Report on the Follow-On Activities to the HOMP Trial, CAA Paper 2004/12, CAA, London, October 2004.

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Part 1 En-route Navigation

1 Introduction

1.1 General

1.1.1 This part of the report examines the hazards associated with en-route navigation for offshore helicopter operations, and focuses on GPS and RNAV-related hazards with the aim of identifying where the use of GPS might remove existing hazards or introduce new ones.

1.1.2 This part of the report is structured as follows:

- Description of en-route operations (Section 2);
- Hazard identification (Section 3);
- Conflict scenario analysis (Section 4);
- Miscellaneous issues (Section 5);
- Conclusions and recommendations (Section 6);
- Functional analysis (Annex A);
- Analysis of MORs (Annex B);
- Risk register analysis (Annex C);
- Accuracy and traffic density (Annex D).

2 Description of en-route operations

2.1 Operating environment

2.1.1 This section describes the existing regulations, procedures, environment, etc. of North Sea helicopter en-route operations. It should be noted that the operations here are quite unique because:

- Most of the airspace is Class G (uncontrolled).
- Traffic operates on both a fixed route structure of helicopter main routes (HMRs) as well as flying 'direct' RNAV routes to/from and between offshore installations.
- In the northern North Sea, VOR/DME reception is available to about 80 NM from Aberdeen but thereafter available intermittently or not at all.
- GPS is the only external navigation aid for significant parts of the airspace.
- ATC provides either a radar advisory service (RAS), modified RAS (MRAS) or radar information service (RIS) to helicopters operating in surveillance radar coverage (up to about 80 miles from Aberdeen and most of the southern North Sea area). Outside of this, where there is still VHF coverage, an enhanced flight information service (EFIS) is provided, which includes information on known conflicting traffic. VHF coverage is available above an altitude of around 1,500ft, but with some 'holes'.

2.1.2 Note that in addition to the procedures described here, installation and commissioning programmes are underway to introduce multilateration and to extend VHF communication coverage by means of re-broadcast stations located on offshore platforms. Multilateration is a surveillance technology that will be introduced into the North Sea. It will provide 'radar-like' surveillance and enable new procedures and much improved monitoring by ATC. The extended VHF communications coverage will eliminate the 'holes' that presently exist, e.g. to the west of the Shetland Islands.

2.1.3 In addition, in–service trials of ACAS II (Airborne Collision Avoidance System, more commonly known as the Traffic alert and Collision Avoidance System, TCAS). are underway, and one operator has committed to full implementation on its North Sea helicopter fleet. This system provides traffic alerts (TAs) of proximate aircraft to improve situational awareness, and avoidance manoeuvres (resolution advisories, RAs) for safety warning for aircraft that are on course to come too close. This system will reduce the risk of mid-air collisions.

2.1.4 Table 3 summarises navigation-related procedures that are presently applicable.

2.2 Airspace and equipment regulations

2.2.1 Regulations covering offshore helicopter operations include:

- the Aeronautical Information Publication (AIP), specifically part ENR 1.15 describing the airspace structure;
- AIC 93/2002, giving the UK policy for the use of GPS;
- JAA AMJ GAI-20 ACJ 20X4, describing B-RNAV requirements;
- JAR OPS 3, specifically IEM to Appendix 1 to JAR OPS 3.430 describing airborne radar approach (ARA) for overwater operations;
- Schedules 4 and 5 of the Air Navigation Order (ANO), describing airborne equipment requirements.

2.2.2 Aircraft operators are also governed by their company procedures and operating manuals. These are accepted by the CAA but do not require CAA approval.

2.2.3 GPS equipment is covered by various equipment standards such as TSO-C129a [7]. ARAs are also described in AC 90-80B (for US procedures) and the Australian Manual of Standards, Part 173.

2.2.4 After leaving the Aberdeen CTZ (Class D), the remainder of the flight is in Class G (uncontrolled) airspace.

2.3 Airspace users

2.3.1 As well as the main helicopter traffic, the airspace is also used by the military and other civil aircraft. Special operations, such as trawler monitoring, also take place. Military users operate in restricted areas (known as Managed Danger Areas or MDAs) but have been known frequently to leave these areas and interact with helicopter traffic.

2.3.2 In the five years up to 2003, average annual helicopter movements from Aberdeen were 40,623 (not including Anglia radar flights or Sumburgh/Scatsta flights).

2.4 Airspace structure

2.4.1 The North Sea airspace used by helicopters is divided into the sectors of Sumburgh, Brent radar (East Shetland Basin), Rebros, Hels and Anglia. All of these areas are operated by Aberdeen ATC. Note that some areas are operated by Aberdeen ATC under delegation from Norway since they are outside of the Scottish FIR.

2.4.2 The area of responsibility is approximately 100,000 sq miles in size and up to FL85 (northern North Sea) and FL65 (southern North Sea).

2.4.3 Helicopter main routes (HMRs) have been established for en-route flight in the northern North Sea and published in the AIP. The HMRs serving Aberdeen are mostly based on a radial structure at 3 degree intervals radiating from Aberdeen VOR/DME (ADN). Alternate routes are used for inbound and outbound traffic. The HMR structure for the southern North Sea is more complex, with many HMRs crossing each other. The route structure for the southern North Sea can be found in the UK AIP ENR 6-1-15-3.

2.4.4 HMRs are defined on the helicopters in an RNAV database by waypoints every 40 miles. When flying outside radar coverage in the northern North Sea, ATC determines helicopter position on the basis of the HMR being flown/crossed and the range from ADN VOR.

2.4.5 Routes are not published for segments between offshore installations (inter-field).

2.4.6 HMRs start at an altitude of 1,500 ft and the first assignable altitude is 2,000 ft. Normally outbound, inbound and inter-field (north/south) traffic fly at different altitudes separated by 1,000 ft.

2.4.7 In the northern North Sea, most outbound flights are at 3,000 ft and inbounds at 2,000 ft. Inter-installation flights are at various altitudes from 500 ft to 3,000 ft.

2.4.8 In the southern North Sea, helicopters will normally plan to fly outbound at 2000 or 3,000ft and inbound at 1,500 and 2,500ft. Inter-installation flights are at various altitudes from 500 ft to 3,000 ft.

2.4.9 Above 3,000 ft MSL the quadrantal rule is applied in the UK. Reciprocal traffic on the HMRs has a vertical separation of 1,000 ft.

2.4.10 Originally, HMRs were aligned with the ADN VOR radials. Due to a gradual shift in magnetic north however, HMRs became offset from the VOR radials by about 1.5 degrees. This caused confusion amongst aircrew, who often reported crossing an HMR when in fact crossing a VOR radial. To alleviate this situation, HMRs were recently re-numbered, so that each HMR is now offset by less than 0.5 degrees from the VOR radial of the same number.

2.5 CNS infrastructure

2.5.1 Radar surveillance and VOR/DME coverage in the northern North Sea is available to traffic at 3,000 ft to about 80 NM range from Aberdeen (covering the Hels sector). Rebros has very little radar coverage and the remaining sectors also have some gaps. Many of the offshore installations are beyond 80 NM, thus the last part of the flight usually takes place in an area without radar and with only intermittent VOR reception.

2.5.2 In the southern North Sea, there is good low level primary and secondary radar coverage over most of the area. There is no radar coverage below 2,000 ft to the north of the Viking field or north-east of the Ravenspurn field.

2.5.3 ATC voice communication is available in most areas above approximately 2000 ft. There are some holes, but work is underway to improve coverage (see 2.1.2 above). VHF communication with Aberdeen is not always available if the aircraft descends during en-route flight (e.g. because of icing). It is important to note that although ATC hears all helicopters and all helicopters hear ATC, due to arrangements in communications transmitters, helicopters may not hear each other when communicating with ATC.

2.5.4 During offshore approaches in the northern North Sea, aircraft are normally outside coverage of surveillance radar and VOR/DME. Below 1,500 ft, VHF communications is available with local offshore installation radio operators and helideck clearance must be obtained from the destination installation prior to landing.

2.5.5 An NDB is available on many offshore installations, but only operated at the request of the aircrew. The NDBs are not calibrated. There are restrictions on operating NDBs as some offshore installations share frequencies. The NDB may be used by the aircrew to identify the installation.

2.5.6 NATS are considering a proposal to install a multilateration system to provide improved surveillance coverage (see 2.1.2 above).

2.6 Airborne navigation equipment

2.6.1 Helicopters flying IFR are required to carry VOR, DME and ADF equipment[1]. GPS equipment may be used as a long-range navigation aid, and RNAV equipment must meet the requirements of JAA AMJ GAI-20, ACJ 20X4 (i.e. B-RNAV).

2.6.2 The RNAV database is provided by a commercial service provider, such as Jeppesen or EAG. Operators may manually add waypoints to them before loading into the RNAV computer.

2.6.3 The RNAV database contains all permanent offshore installations, HMRs and IFR departure and arrival routes. Aircrew can enter temporary waypoints prior to or during flight but cannot edit the permanent waypoints. Cross-track routes may be flown using the 'direct to' function, but would usually be assembled by the crew using permanent and temporary waypoints as required.

2.6.4 The RNAV CDI is operated at 1 NM full scale deflection in en-route mode. (TSO-C-129a [7] specifies a full scale deflection of 5 NM for en-route flight. Therefore it should be checked by the aircrew and may have to be manually changed.)

2.6.5 Stand-alone GPS equipment includes the Thales RNAV-2 and Free Flight 2101. The Thales 'RNAV-2' system allows for cross-checking of position between VOR/DME and GPS when flying on a radial. It will generate a warning if there is more than a 5 NM variation between the two positions.

2.6.6 Most offshore helicopters are fitted with weather radar, which shows ground features such as coastlines, towns, ships, and offshore installations. Most weather radar displays can overlay RNAV information on the radar display, to allow RNAV and radar information to be easily cross-checked.

2.7 ATC services

2.7.1 In uncontrolled airspace the Aberdeen ATSU provides the following services, depending on the region:

- Alerting service. The requirements of the alerting service dictate the intervals that controllers specify to aircrew for their position/ops normal reports.
- Radar Advisory Service (RAS) or Modified Radar Advisory Service (MRAS). Modified RAS is only available to participating helicopter operators. It removes from ATC the responsibility for terrain clearance permitting helicopters to descend in connection with their limited icing clearance procedures.
- Radar Information Service (RIS).
- Flight Information Service (FIS) or Enhanced Flight Information Service (EFIS).

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[1] It is noted that the ANO schedule 5 permits Decca equipment as an alternative. It may be appropriate to change the ANO as the Decca service is no longer available.

2.7.2 Definitions of RAS, RIS and FIS are given in Table 1 below.

Table 1 Definitions of RAS, RIS and FIS

Service	**Definition**
Radar advisory service (RAS)	A RAS is an air traffic radar service in which the controller shall provide advice necessary to maintain prescribed separation between aircraft participating in the advisory service, and in which he shall pass to the pilot bearing, distance and, if known, level of conflicting non-participating traffic, together with advice on action necessary to resolve the confliction. Where time does not permit this procedure to be adopted, the controller shall pass advice on avoiding action followed by information on the conflicting traffic. Even though the service is an advisory one, controllers shall pass the 'advice' in the form of instructions.
Radar information service (RIS)	A RIS is an air traffic service in which the controller shall inform the pilot of the bearing, distance and, if known, the level of the conflicting traffic. No avoiding action shall be offered. The pilot is wholly responsible for maintaining separation from other aircraft, whether or not the controller has passed traffic information.
Flight information service (FIS)	Provision of the service includes information about weather, changes of serviceability of facilities, conditions and aerodromes and any other information pertinent to safety.The controller may attempt to identify the flight for monitoring and co-ordination purposes only. Such identification does not imply that a radar service is being provided or that the controller will continuously monitor the flight. Pilots must be left in no doubt that they are not receiving a radar service. Controllers are not responsible for separating or sequencing aircraft.

2.7.3 Note that in RAS, ATC provide separation to other aircraft participating in the service. In RIS and FIS, the pilot is responsible for maintaining separation.

2.7.4 In the RAS, the following separation standards are applied:

- Known traffic: 5 NM (10 NM outside of 80 NM) or 1,000 ft vertical. Visual separations may be applied for MRAS traffic.
- Unknown traffic, Mode C displayed: 5 NM (10 NM outside 80 NM) or 3,000 ft vertical.
- Unknown traffic, no Mode C displayed: 5 NM (10 NM outside 80 NM).

2.7.5 In the EFIS service, ATC passes information for traffic passing with vertical separation of less than 1,000 ft and the following parameters:

- For traffic on opposite direction HMRs with <6 degree separation, pass traffic information when position reports indicate <40 NM lateral separation.
- For traffic on same direction HMRs with <6 degree separation (i.e. the same HMR), pass traffic information when position reports indicate <10 NM lateral separation.
- For traffic crossing an HMR, pass traffic information when position reports indicate <20 NM lateral separation.

2.7.6 In the Rebros sector, three offshore transmitter/receivers receive and re-broadcast transmissions. The offshore transmitters are at Forties B, Fulmar A and Brae A.

2.7.7 In the Brent radar sector, radar services are provided using a source located outside UK and owned by another National Authority. This gives radar coverage to 1,000ft throughout the East Shetland Basin.

2.7.8 When out of radar coverage, helicopters are requested by ATC to make position/ops normal reports. This is primarily for the alerting service, and ATC must take action if a report is not received for 15 minutes. Hence ATC normally requests a report slightly more frequently (usually every 20 miles along an HMR).

2.7.9 The lower limit of RAS is 2,500 ft. MRAS does not have a lower limit as ATC do not have responsibility for terrain clearance. ATC do not have any responsibility below 1,500ft in Rebros but do in some other sectors. Below 1,500ft, approaching installations, aircrew switch to a local frequency where a local radio operator is available. ATC do not normally handle communications below 1,500ft, however, they would normally respond if contacted by a flight crew.

2.8 Pre-flight procedures

2.8.1 Several hours before the flight, the intended route is communicated to the local ATSU in what is termed a 'mayfly' or 'abbreviated flight plan' but this does not contain all the details that are included in a standard ICAO flight plan.

2.8.2 Immediately before flight, the aircrew program the route into the RNAV computer. This may include entering temporary waypoints for mobile installations. The need to carry out an ARA is not normally decided upon at the pre take-off stage - it will be dependent upon the latest weather report from the installation passed approximately 20 minutes before arrival. The use of temporary waypoints to align the helicopter with the final approach track can be advantageous and it may be possible to do without the initial segment of the procedure if a course reversal manoeuvre is unnecessary.

2.8.3 Temporary waypoints are cross-checked by the second crew member before confirmation.

2.8.4 Note that JAA AMJ GAI-20 ACJ 20X4 (B-RNAV requirements) also requires these pre-flight checks:

- Check of RAIM availability for the intended route, if the GPS constellation comprises 23 or less satellites. Dispatch of flights dependant upon GPS for primary navigation should not be made in the event of more than 5 minutes of predicted continuous loss of RAIM on any part of the intended flight.
- The validity of the database (current AIRAC cycle) should be checked. Note that the GPS equipment should annunciate any out-of-date database.

2.9 Take-off and En-route procedures

2.9.1 After take-off, helicopters may be vectored out of the Control Zone and then given a direct clearance to 80 NM on an HMR. This means that they may be crossing HMRs before they are established on the HMR that they will follow out to 80 NM.

2.9.2 The helicopters then follow the HMRs until they break away towards the destination installation. The point at which they depart the HMR is dependent on traffic and weather conditions. In good visibility and favourable traffic conditions, ATC may allow the helicopters to fly direct to the platform.

2.9.3 The aircrew should advise ATC at the point at which they depart from the HMR, although ATC reports that this is not always the case. The aircrew should also advise if they deviate from the planned route, e.g. because of weather.

2.9.4 When in a FIS or EFIS service, ATC will not issue or deny 'clearances'.

2.9.5 Aircrew are required to undertake cross-checks between navigation sources every 20 minutes. This is only feasible when in range of the Aberdeen VOR.

2.9.6 Aircrew establish communications with the destination installation while still within Aberdeen ATC communications coverage. On the return leg, the aircrew contact Aberdeen ATC when airborne and while still in communications contact with the installation.

2.9.7 Outside radar coverage, helicopters report their position every 20 NM if flying along HMRs, or every 10 minutes if flying across HMRs. Within radar coverage, helicopters are not required to report their position.

2.9.8 In the case of the aircrew detecting a navigation error, such as erroneous navigation output or incorrect data, the aircrew shall:

- if within radar coverage, request vectors from ATC;
- if not within radar coverage, use ADF, VOR, DME, weather radar and DR to reach the destination or alternate.

2.9.9 In the case of loss of RAIM, the aircrew checks for rapid changes in heading (this would indicate a probable RNAV failure) and/or check GPS position against other navigation sources and continue unless they identify a reason not to.

2.9.10 Note that JAA AMJ GAI-20 ACJ 20X4 does not require cross-checks of RNAV information. Initial procedures for GPS offshore operations included regular cross-checks against a manual DR plot at intervals not exceeding 15 minutes. However, this is not performed because the wind information needed to produce the DR plot is provided by GPS. Therefore any error in GPS would also lead to an error in the DR calculation.

2.9.11 In the case of total loss of GPS or navigation when outside of range of other navaids, the aircraft will either:

- if within radar coverage, request vectors from ATC;
- if not within radar coverage, continue using DR if possible and mapping radar to establish position. (Intermittent reception of some land-based NDBs is possible even at distant installations, and this has been used to assist return to radar coverage after GPS equipment failure)

2.9.12 In the case of a report of 'GPS unserviceable', NATS staff will use their discretion to provide additional flight information to the aircraft concerned or other aircraft nearby.

2.9.13 NATS staff estimate that a 'GPS unserviceable' event occurs about once a week, but there is no data that accurately records instances of equipment failure.

2.10 **Post-flight procedures**

2.10.1 The flight crew would consider filing mandatory occurrence reports (MORs) to the CAA in the case of any incident which endangers or, if not corrected, would endanger an aircraft, its occupants or any other person, or company voyage reports or air safety reports (ASRs) in the case of less serious failures.

2.10.2 Temporary waypoints entered into the database need not be cleared and may be used by the next flight crew, subject to verification of the coordinates.

2.11 Implications of incorrect navigation

2.11.1 In the North Sea environment, the possible implications of incorrect navigation are:

Table 2 Implications of incorrect navigation

Implication	Comments
A conflict with another aircraft.	Aircrew are responsible for maintaining separation with assistance from ATC. ATC provide information on proximate known aircraft and will advise helicopters to help maintain separation.
Wrong information provided to SAR in case of helicopter ditching.	ATC provide an alerting service that sometimes depends on the position reports from the aircraft.
Aircrew unable to find an airport or helideck to land.	
Helicopter in conflict with terrain or obstacle.	In MRAS and EFIS the pilot takes responsibility for terrain/obstacle clearance. Therefore this hazard is not considered further in this analysis.
Helicopter enters reserved airspace.	There are some military managed danger areas in the North Sea but all are well above the altitudes normally flown by helicopters. Therefore this hazard is not considered further in this analysis.

2.12 Current procedures

2.12.1 Table 3 summarises the current procedures for the navigation system (including GPS) including checks and failure procedures.

Table 3 Current navigation system (inc GPS) failure mitigation procedures

Action	Comments
Normal operation	
RAIM check pre-flight	Required if 23 or fewer satellites in GPS constellation. Value to helicopter operations may be questionable since the software tools available for this are designed for fixed-wing operations and take no account of GPS antenna reception characteristics.
Aircrew cross-check entry of temporary waypoints	
Navigation database is updated each AIRAC cycle	
CDI[1] is set to 1 NM full scale deflection	Impacts on navigation flight technical error. Some RNAV systems may default to 5 NM.
Regular cross-checks (e.g. fuel remaining)	Undertaken every 20 minutes.
Aircrew report position when in EFIS	Report rate of 15 minutes maximum is primarily driven by SAR alerting requirements. This would only allow ATC to detect gross errors.
ATC pass information on conflicting traffic	Separation remains aircrew responsibility.

Table 3 Current navigation system (inc GPS) failure mitigation procedures (Cont.)

Action	Comments
RAIM lost or exceeded	
Aircrew report to ATC	Time waited before contacting ATC may not be consistent.
ATC widens the parameters within which traffic information is passed for EFIS	At discretion of ATC.
Cross-check against whichever other navigation sources available	Subject to availability of something to cross-check against.
GPS unserviceable or navigation equipment failure	
Aircrew report to ATC	Time waited before contacting ATC may not be consistent.
ATC widens the parameters within which traffic information is passed for EFIS	At discretion of ATC.
Alternative navigation, e.g. DR or NDB where reception possible	Subject to availability of alternative navigation source.DR should not be attempted if GPS gives obvious wrong position, as it will also give erroneous wind.

1. It is assumed in this analysis that deviation from track is displayed on the Course Deviation Indicator (CDI). The CDI may be a standalone instrument or be integrated within the Horizontal Situation Indicator (HSI).

3 Hazard identification

3.1 Introduction

3.1.1 This section presents the top-level hazards associated with en-route navigation that were identified in the study. They have been derived from three sources:

- Discussions with helicopter operators.
- A functional analysis (see Annex A).
- Review of previous documentation (see Annex C).

3.1.2 The hazards were merged into a consolidated list, as shown in Table 4:

Table 4 Summary of hazards

ID	Hazard
1	Navigation database is unreliable
2	Navigation database is outdated
3	Crew selects wrong route
4	Navigation is degraded
5	Loss of navigation

3.1.3 Note that not all of these hazards are GPS-specific. Some are generic RNAV hazards, e.g. navigation database is unreliable. The hazards are described in the following sections.

3.2 ID1: Navigation database is unreliable

3.2.1 The navigation database used for offshore helicopter operations contains the following information:

- Positions of aerodromes and fixed installations together with approach fixes.
- HMRs and waypoints.
- SIDs and STARs.

3.2.2 This database may contain errors. The errors may be introduced at any stage in the database development process, for example:

- Before publication in the AIP.
- If the operator adds data before loading the database onto the helicopter.

3.2.3 It may also be the case that the AIP is correct, but that the database provider incorrectly codes the procedure or waypoints.

3.3 ID2: Navigation database is outdated

3.3.1 This hazard may arise for a number of reasons (page 32 of [5]):

- The operator does not update the database for the current AIRAC cycle.
- The database provider fails to incorporate all the changes in a new AIRAC cycle.

3.3.2 It is the operator's responsibility to ensure that the correct version of the database is loaded on the aircraft. It is the responsibility of the flight crew to check that the correct database is being used prior to departure.

3.4 ID3: Crew selects wrong route

3.4.1 This hazard occurs if the crew select the wrong route or other data from the navigation database. For example, if the pilot selects valid waypoints which are not on the planned flight path or if the pilot incorrectly enters temporary waypoints.

3.4.2 Another example is that crews may enter temporary waypoints either for mobile installations or for approach fixes. Typically, these waypoints are not cleared when the crew finishes the operation. If a new crew enters temporary waypoints of a similar name into the RNAV computer, confusion may arise between the old and the newly entered waypoints.

3.5 ID4: Navigation is degraded

3.5.1 GPS navigation performance can be degraded for a number of reasons, including degradation of GPS signals-in-space, GPS sensor error, area navigation system errors, or display system errors.

3.5.2 The degradation of GPS signal-in-space performance may be caused by:

- Satellite error (e.g. clock drift) or unavailability, either notified or unannounced.
- Poor GPS constellation geometry or shielding of satellites by the helicopter fuselage, rotor blades or the destination structure.
- Intentional or unintentional interference with the GPS signal-in-space, i.e. jamming.

3.5.3 If GPS availability drops below the level required for RAIM, the position solution is no longer checked for integrity (this does not necessarily mean that navigation accuracy is reduced). According to TSO-C129a [7] requirements for a GPS receiver, the pilot should receive a clear annunciation of such an event.

3.5.4 Other causes of degradation of GPS navigation performance include:

- GPS receiver hardware or software failures.
- Inaccuracy in the CDI output from the area navigation system.

3.5.5 Degraded navigation can be separated into two categories:

- Navigation degraded and the pilot is aware (e.g. through a system warning or cross–check).
- Navigation degraded and the pilot is not aware.

3.6 ID5: Loss of navigation

3.6.1 In this hazard, navigation is lost completely. Specifically, in the context of this study, the hazard is that GPS navigation is lost. This could arise due to:

- Loss of GPS signal-in-space due to system failure or jamming. In the extreme case, satellite availability may drop below the level required for position determination. Signal power could also fall to a level below that required for adequate reception.
- Loss of on-board ability to receive or analyse GPS satellite signals. This could be due to:
  - a failure of the GPS receiver;
  - a failure of the aircraft's antenna;
  - a failure of GPS position display;
  - a failure of the aircraft’s wiring associated with GPS.

4 Conflict scenario analysis

4.1 Introduction

4.1.1 Conflict scenarios are used to analyse the operational impact of hazards. A conflict scenario represents an operational consequence of a hazard. Several hazards may result in the same operational consequence.

4.1.2 Three conflict scenarios have been identified:

- The helicopter flies a different route to the one intended (CS1).
- Bad quality of aeronautical data causes deviation from the intended route (CS2).
- Incorrect position estimation causes deviation from the intended route (CS3).

4.1.3 Table 5 shows the links between the conflict scenarios and the hazards identified in Section 2:

Table 5 Link between conflict scenarios and hazards

Ref.	Description	CS1	CS2	CS3
ID1	Navigation database is unreliable		✓	
ID2	Navigation database is outdated	✓		
ID3	Crew selects wrong route	✓		
ID4	Navigation is degraded			✓
ID5	Loss of navigation			✓

4.1.4 Note that the hazard classification applies to how operations are currently conducted. Hence existing mitigations inherent to these operations are assumed when determining severities and probabilities. Once the risk tolerability matrix is defined for each conflict scenario, existing and additional (new) mitigations will be formally identified as necessary.

4.1.5 It should also be noted that the following analysis has been carried out for the operational environment that exists in the northern North Sea. Section 4.4.5 explains the applicability of this analysis to the southern North Sea.

4.2 Conflict Scenario 1: Incorrect flight crew route selection/database checking causes helicopter to fly different route to the one intended

4.2.1 Description

4.2.1.1 In this conflict scenario, the helicopter flies a route other than the one it was cleared for. This conflict scenario is caused by crew error in terms of waypoint selection for the intended route (crew will usually input the whole route in one go). Another causal factor for this conflict scenario is the crew not checking the validity of the navigation database (data in the previous version may no longer be valid).

4.2.1.2 The two hazards that can cause this conflict scenario are ID2 (navigation database is outdated) and ID3 (crew selects wrong route).

4.2.1.3 It is assumed that the crew may or may not be aware of the difference in route, but they are aware of their current position.

4.2.2 Severity

4.2.2.1 Flying the wrong route may have no safety impact if, for example, there are no other aircraft in the vicinity. This section focuses on events that have a safety impact as a result of flying the wrong route. The possible implications of flying the wrong route include (see Section 2.11):

- a conflict with another aircraft;
- wrong information provided to SAR in case of helicopter ditching;
- aircrew unable to find an airport/airfield or helideck to land.

4.2.2.2 The chains of events that could lead to the above implications are shown in Table 6 along with their assigned severities.

Table 6 Consequence analysis for Conflict Scenario 1

Event	Chain of events required	Severity
A1) A conflict with another aircraft while crossing a HMR	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to notice and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
A2) A conflict with another aircraft while flying same direction on incorrect HMR	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to notice and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
A3) A conflict with another aircraft while flying opposite direction on incorrect HMR	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to notice and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
B) Wrong information provided to SAR in case of helicopter ditching	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fail to notice AND ATC fails to notice and rectify AND Helicopter ditches AND ELT not deployed or fails	HAZARDOUS
C) Aircrew unable to find an airport or helideck to land	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fail to notice AND ATC fails to notice and rectify AND Helicopter unable to find any suitable landing zone before fuel runs out	HAZARDOUS

4.2.3 Probability

4.2.3.1 The probability of a deviation being caused by human error when entering a pre-programmed route is discussed in [11], which estimates this probability to be 5 x 10^{-4} and 5 x 10^{-5} per flight. Assuming that a flight in North Atlantic region (from where the data is taken) takes about 5 hours, this translates to a probability of between 1 x 10^{-4} and 1 x 10^{-5} per hour. Given that the flight crew will usually enter the whole route in one selection (by selecting the HMR to fly on), it is assumed that the probability of error is at the lower limit of the range, 1 x 10^{-5} per hour.

4.2.3.2 The same probability, 1 x 10^{-5} per hour, is also assumed for the event of the flight crew not spotting that the database is not valid.

4.2.3.3 Outside of RAS/RIS (i.e. in EFIS), the probability of occurrence is estimated by combining together multiple probabilities as shown in Table 7.

4.2.3.4 In this CS analysis, as in all the others in this report, all probabilities are rounded to the nearest order of magnitude probabilities. This is to ensure a consistent resolution in the figures, and avoid false over-confidence in the accuracy of the calculations.

Table 7 Probability analysis for Conflict Scenario 1 in EFIS

Event	Chain of events required	Probability (per flight hour)
A1) A conflict with another aircraft while crossing HMR	Incorrect flight crew route selection/database checking causes deviation from intended path AND	1 x 10^{-5}
	Flight crew fails to detect and rectify AND	1 x 10^{-2} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Another aircraft in the vicinity without vertical separation AND	1 x 10^{-3} (note 3)
	Flight crew fail to see and avoid other helicopter	1 x 10^{-2} (note 7)
		Total: 1 x 10^{-12} LESS THAN EX. IMPROBABLE
A2) A conflict with another aircraft while flying same direction on incorrect HMR	Incorrect flight crew route selection/database checking causes deviation from intended path AND	1 x 10^{-5}
	Flight crew fails to notice AND	1 x 10^{-2} (note 1)
	ATC fails to notice and rectify AND	1 (note 2)
	Another aircraft in the vicinity without vertical separation AND	1 x 10^{-1} (note 3)
	Flight crew fail to see and avoid other helicopter	1 x 10^{-2} (note 7)
		Total: 1 x 10^{-10} EX. IMPROBABLE

Table 7 Probability analysis for Conflict Scenario 1 in EFIS (Cont.)

A3) A conflict with another aircraft while flying opposite direction on incorrect HMR	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fails to notice AND ATC fails to notice and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	1 x 10^{-5} 1 x 10^{-2} (note 1) 1 (note 2) 1 x 10^{-4} (note 3) 1 x 10^{-2} (note 7) **Total: 1 x 10^{-13}** LESS THAN EX. IMPROBABLE
B) Wrong information provided to SAR in case of helicopter ditching	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fails to notice AND ATC fails to notice and rectify AND Helicopter ditches AND ELT not deployed or fails	1 x 10^{-5} 1 x 10^{-2} (note 1) 1 (note 2) 1 x 10^{-5} (note 4) 1 x 10^{-1} (note 5) **Total: 1 x 10^{-13}** LESS THAN EX. IMPROBABLE
C) Aircrew unable to find an airport or helideck to land	Incorrect flight crew route selection/database checking causes deviation from intended path AND Flight crew fails to notice AND ATC fails to notice and rectify AND Helicopter unable to find any suitable landing zone before fuel runs out	1 x 10^{-5} 1 x 10^{-2} (note 1) 1 (note 2) 1 x 10^{-5} (note 6) **Total: 1 x 10^{-12}** LESS THAN EX. IMPROBABLE
Note 1: Assumed - see 4.2.3.6. Note 2: It is assumed that ATC does not detect the error until the next position report. Note 3: See Annex D for collision risk in the case of crossing tracks and flying in the same or opposite direction along an HMR. Note 4: Assumed - see 4.2.3.8. Note 5: Assumed - see 4.2.3.9. Note 6: Assumed, however it is noted that a thousand times increase in the assumed probability of this event will not affect the criticality of the failure, the failure rate staying within 'acceptable' limits. Note 7: Assumed - see 4.2.3.7.		

4.2.3.5 The importance of expert judgement for these figures should be noted. For some figures, no quantitative data are available. The uncertainty in the probabilities calculated should be borne in mind when considering the tolerability of different events.

4.2.3.6 In particular, the probability of the flight crew failing to notice a navigational error is dependant on a number of factors such as workload and the size of the error. Consultation with human factors specialists within the CAA has indicated that no definitive data exist that are relevant to this scenario. However, CAA specialists have confirmed that the probability assumed is of the correct order in their view.

4.2.3.7 The probability of failing to see and avoid the conflicting helicopter is assumed to be 10^{-2} in VMC. This probability is derived in Part 2 - 4.2.5 of the report and applied to each helicopter in a conflict situation to give a probability of both crew failing to see and avoid of 10^{-4}. Since helicopters on the HMRs may be flying in IMC, a net probability of 10^{-2} has been applied in this scenario.

4.2.3.8 The helicopter ditching rate of 1×10^{-5} has been taken from [14]. The ditching rate for the period following this reference is lower (a number of the ditchings that led to the earlier higher rate were due to a specific cause that has been rectified), however the higher rate has been used for the hazard analysis in the interests of conservatism.

4.2.3.9 Although the reliability of the ADELT (Automatically Deployable ELT) has been poor, it should be noted, that each helicopter would have at least 4 ELTs on board. A probability of 10^{-1} has been assumed.

4.2.3.10 Within (M)RAS/RIS, ATC monitor traffic on surveillance radar to detect potential conflicts. Therefore any aircraft that deviates and, as a result, comes into conflict with another aircraft will be detected by ATC. Note that ATC are not responsible for aircraft navigation and may not detect a deviation from the flight plan that does not result in potential conflict. The probability of unsuccessful ATC detection is assumed at 10^{-3} to 10^{-4} ([11]) which, when combined with the above probabilities, takes all 'A' events to LESS THAN EXTREMELY IMPROBABLE.

4.2.4 Risk tolerability

4.2.4.1 Table 8 shows a summary of conflict scenario 1, based on the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 8 Summary of Conflict Scenario 1

Conflict Scenario 1: Incorrect flight crew route selection/database checking causes deviation from intended path			
	Severity	**Probability**	**Result**
Undetected selection error leads to helicopter flying the wrong route	Within (M)RAS/RIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) LESS THAN EX. I. A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) NEGLIGIBLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE

4.2.4.2 In the table above, all cases but one (A2 within EFIS) result in NEGLIGIBLE classifications. There is one case that would be TOLERABLE; a deviation leading to the helicopter joining the wrong same-direction track on the return from an installation within EFIS.

4.2.4.3 The following additional mitigations are proposed to address this case:

- A procedure should be defined to delete out-of-date temporary waypoints from the RNAV database.
- A manual cross-check of each temporary waypoint against known data (e.g. range/ bearing from a known point).
- A position report to ATC when joining an HMR outside radar coverage.

4.2.4.4 It is recommended that these mitigations be discussed with the helicopter operators.

4.2.4.5 It is also recommended that aircrew should undertake cross-checks against a non-RNAV navigation source if flying outside of VHF coverage (outside of VHF coverage, there is no cross-check of position reports by ATC) or at any other times when risk may be increased (e.g. when icing conditions require a deviation from normal flight levels). Acceptable checks would be:

- Check of weather radar display against positions of known installations.
- Check of position against an NDB where possible. To support this, one or more permanent NDBs could be positioned on a fixed installation.
- Check against remaining fuel, although in some circumstances this may not detect the error.

4.3 Conflict scenario 2: Incorrect of aeronautical data causes deviation from intended path

4.3.1 Description

4.3.1.1 This conflict scenario considers the case where the helicopter crew are presented with incorrect database information for navigation. For the en-route phase, the relevant information includes:

- Positions of airports/airfields and fixed installations together with approach fixes.
- HMRs and waypoints.

4.3.1.2 In this case, the aircraft deviates from its intended route but does not follow any other HMR.

4.3.1.3 This conflict scenario can be caused by hazard ID1 (navigation database is unreliable).

4.3.2 Severity

4.3.2.1 While the severity of track deviations depends on the size of deviation, even deviations of a few NM could create a significant conflict risk in some parts of the airspace.

4.3.2.2 As for conflict scenario 1, the severity is estimated by showing the chains of events that could lead to more serious implications. These are shown below along with their assigned severities in Table 9.

4.3.2.3 Note that there is a further hazard, not assessed further here, whereby the aircrew detect the deviation before it happens and correct it. This adds minor workload but it is not expected to pose any significant safety hazard.

Table 9 Consequence analysis for Conflict Scenario 2

Event	Chain of events required	Severity
A1) A conflict with another aircraft while crossing a HMR	Incorrect aeronautical data causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
A2) A conflict with another aircraft while flying same direction on incorrect HMR	Incorrect aeronautical data causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
A3) A conflict with another aircraft while flying opposite direction on incorrect HMR	Incorrect aeronautical data causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
B) Wrong information provided to SAR in case of helicopter ditching	Incorrect aeronautical data causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to detect and rectify AND Helicopter ditches AND ELT not deployed or fails	HAZARDOUS
C) Aircrew unable to find an airport or helideck to land	Incorrect aeronautical data causes deviation from intended path AND Flight crew fail to notice and rectify AND ATC fails to detect and rectify AND Helicopter unable to find any suitable landing zone before fuel runs out	HAZARDOUS

4.3.3 Probability

4.3.3.1 Navigation databases are required to have integrity of 10^{-5} by ICAO Annexes 11 and 15. However studies (see page 41 of [4]) have highlighted discrepancies in data from various database providers and data from AIPs, and concluded that some data are outside ICAO Annex 15 tolerances. The hazard analysis [11] estimates a probability of database error of 2×10^{-4}. However, the North Sea data changes very infrequently, therefore the probability of errors should be reduced. We therefore assume a figure of 2×10^{-5}.

4.3.3.2 Within EFIS, the probability of occurrence is estimated by combining together multiple probabilities as shown in Table 10.

Table 10 Probability analysis for Conflict Scenario 2

Event	Chain of events required	Probability (per flight hour)
A1) A conflict with another aircraft while crossing HMR	Incorrect aeronautical data causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Another aircraft in the vicinity without vertical separation AND	1×10^{-3} (note 3)
	Flight crew fail to see and avoid other helicopter	1×10^{-2} (note 7)
		Total: 1×10^{-12} LESS THAN EX. IMPROBABLE
A2) A conflict with another aircraft while flying same direction on incorrect HMR	Incorrect aeronautical data causes deviation from intended path AND	2×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Another aircraft in the vicinity without vertical separation AND	1×10^{-1} (note 3)
	Flight crew fail to see and avoid other helicopter	1×10^{-2} (note 7)
		Total: 2×10^{-10} EX. IMPROBABLE
A3) A conflict with another aircraft while flying opposite direction on incorrect HMR	Incorrect aeronautical data causes deviation from intended path AND	2×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Another aircraft in the vicinity without vertical separation AND	1×10^{-4} (note 3)
	Flight crew fail to see and avoid other helicopter	1×10^{-2} (note 7)
		Total: 2×10^{-13} LESS THAN EX. IMPROBABLE

Table 10 Probability analysis for Conflict Scenario 2 (Cont.)

Event	**Chain of events required**	**Probability (per flight hour)**
B) Wrong information provided to SAR in case of helicopter ditching	Incorrect aeronautical data causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Helicopter ditches AND	1×10^{-5} (note 4)
	ELT not deployed or fails	1×10^{-1} (note 5)
		Total: 1×10^{-13} LESS THAN EX. IMPROBABLE
C) Aircrew unable to find an airport or helideck to land	Incorrect aeronautical data causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Helicopter unable to find any suitable landing zone before fuel runs out	1×10^{-5} (note 6)
		Total: 1×10^{-12} LESS THAN EX. IMPROBABLE

Note 1: Assumed - see 4.2.3.6.
Note 2: It is assumed that ATC does not detect the error until the next position report.
Note 3: See Annex D for collision risk in the case of crossing tracks and flying in the same or opposite direction along an HMR.
Note 4: Assumed - see 4.2.3.8.
Note 5: Assumed - see 4.2.3.9.
Note 6: Assumed, however it is noted that a thousand times increase in the assumed probability of this event will not affect the criticality of the failure, the failure rate staying within 'acceptable' limits.
Note 7: Assumed - see 4.2.3.7.

4.3.3.3 As with conflict scenario 1, within (M)RAS/RIS, the probability of unsuccessful ATC detection is assumed at 10^{-3} to 10^{-4} which takes all risks to LESS THAN EXTREMELY IMPROBABLE.

4.3.4 Risk tolerability

4.3.4.1 Table 11 shows a summary of conflict scenario 2, using the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 11 Summary of Conflict Scenario 2

Conflict Scenario 2: Incorrect aeronautical data causes deviation from intended path			
	Severity	**Probability**	**Result**
The use of incorrect aeronautical data leads to a track deviation	Within (M)RAS/RIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) LESS THAN EX. I. A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) NEGLIGIBLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE

4.3.4.2 As for conflict scenario 1, only one case (A2 within EFIS) results in anything worse than an NEGLIGIBLE risk. The same mitigations should be applied as for conflict scenario 1 to address this risk (see 4.2.4.3).

4.4 Conflict Scenario 3: Incorrect position estimation causes deviation from intended path

4.4.1 Description

4.4.1.1 This conflict scenario considers the case where the helicopter deviates from its intended route due to incorrect or unavailable position information from the navigation system. This assessment focuses on loss or degradation of GPS but also identifies other system failures.

4.4.1.2 The two hazards that cause this conflict scenario are ID4 (navigation is degraded) and ID5 (loss of navigation). The following cases are considered:

- Case 1: RAIM unavailable (crew aware);
- Case 2: RAIM limit exceeded (crew aware);
- Case 3: RAIM limit exceeded/RAIM unavailable (crew unaware);
- Case 4: Position estimate not available.

4.4.2 Severity

Case 1: RAIM unavailable (crew aware)

4.4.2.1 If the satellite availability drops below the level required for RAIM, TSO-C129a [7] states that the flight crew should receive a warning. In such a case, the GPS position provided is no longer checked for integrity, and therefore the crew would not be alerted to an erroneous position solution. A loss of RAIM does not necessarily mean that GPS navigation is significantly degraded.

4.4.2.2 Short RAIM outages do not have a significant operational effect.

4.4.2.3 For longer outages, the flight crew should check GPS position against other navigation sources if available, and also check for rapid changes in heading (this would indicate a probable RNAV failure). A longer outage should be notified to ATC, although it is not clear if all operators have consistent procedures in this area. It is recommended that minimum procedures are standardised with operators, particularly the time before contacting ATC. A suitable time before contacting ATC could be 2 minutes (to be discussed with operators).

4.4.2.4 Given that the crew is aware of the loss of RAIM and assuming they can undertake remedial actions, this scenario is assigned a severity of MINOR.

Case 2: RAIM limit exceeded (crew aware)

4.4.2.5 TSO-C129a [7] states that if the error in the position solution from GPS in the en-route phase exceeds 2 NM, a warning should be annunciated to the flight crew within a maximum of 30 seconds of the deviation being detected.

4.4.2.6 As with a RAIM outage, the crew would undertake remedial actions including: notifying ATC, cross-check against other navigation sources and check for rapid changes in heading. If the crew reverts to DR, they should not use the wind information from GPS since it may be incorrect if RAIM is unavailable.

4.4.2.7 Given that reversion to DR in a two-pilot environment would not cause a significant increase in workload, this scenario is assigned a severity of MINOR. If the operation was single pilot IFR, then reversion to DR and the added workload might justify an increase in severity to MAJOR.

Case 3: RAIM limit exceeded/RAIM unavailable (crew unaware)

4.4.2.8 Typical failures in this case are caused by the receiver not detecting when the RAIM limit is exceeded or introducing an unrelated error that exceeds RAIM limits. In either case, the flight crew is not alerted by the GPS equipment to the navigation errors introduced.

4.4.2.9 The chain of consequences is analysed as follows in Table 12.

Table 12 Consequence analysis for Conflict Scenario 3, Case 3

Event	Chain of events required	Severity
A1) A conflict with another aircraft while crossing a HMR	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crews fail to see and avoid other helicopter	CATASTROPHIC
A2) A conflict with another aircraft while flying same direction on incorrect HMR	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC

Table 12 Consequence analysis for Conflict Scenario 3, Case 3 (Cont.)

Event	Chain of events required	Severity
A3) A conflict with another aircraft while flying opposite direction on incorrect HMR	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
B) Wrong information provided to SAR in case of helicopter ditching	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Helicopter ditches AND ELT not deployed or fails	HAZARDOUS
C) Aircrew unable to find an airport or helideck to land	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Helicopter unable to find any suitable landing zone before fuel runs out	HAZARDOUS

Case 4: Position estimate not available

4.4.2.10 This can arise because of a loss of GPS signals-in-space or equipment failure. TSO-C129a [7] states that if the GPS system fails (either the signal-in-space or the receiver), the crew will be automatically alerted by the GPS avionics. The crew is aware that position is unavailable.

4.4.2.11 In the case of a helicopter established en-route, the following action would be taken by the crew:

- Notify ATC.
- If within ATC radar coverage, request vectors from ATC.
- Otherwise, revert to DR. (But note that wind information will not be available if GPS has failed.)
- It may also be possible to maintain a steady course until a position fix can be determined (this could be achieved by a mixture of visual and weather radar cues).

4.4.2.12 For helicopters flying outbound, the helicopter is likely to be already on the appropriate heading. For helicopters flying inbound, the crew are aware of the anticipated return route. In both cases, the loss of GPS will not be a significant issue, because the crew is immediately aware of the problem, and can take appropriate measures, e.g. cross-check with other data. Therefore, as for Case 2, this scenario is assigned a severity of MINOR, assuming a two-pilot environment.

4.4.2.13 If a navigation failure occurs prior to take-off from an installation, it would be advisable for the installation radio operator to inform ATC prior to take-off. ATC can then check that traffic density around the return route is not high and, if necessary, delay the flight until traffic is lighter.

4.4.2.14 Note that this hazard may simultaneously affect many aircraft if there is a total failure of the GPS system. Increased navigation uncertainty for all aircraft could result in an increased hazard and it may be appropriate for ATC to increase the separation minima that it applies between aircraft. It is recommended that this is discussed with ATC.

4.4.3 Probability

Case 1: RAIM unavailable (crew aware)

4.4.3.1 Operators have reported a number of short-lived (10 seconds or less) RAIM outages due to the lack of visible satellites. However, there were no reports of outages of sufficient duration to impact on operations. Therefore, this probability is assigned REMOTE but a formal validation against operational data is recommended.

4.4.3.2 There is a lack of data on the frequency of short outages, but this would be useful to gather as it could provide an indication of changes in the performance of GPS. In addition, ICAO Annex 10 para. 2.4.3.1 recommends recording of relevant data both for accident and incident investigations, and to support periodic confirmation that system performance remains adequate for the operations approved.

4.4.3.3 [12] reports that RAIM availability for integrity monitoring for horizontal position for Non Precision Approach (NPA) is less than 98% in mid latitude regions. (The horizontal alert limit (HAL) used for NPA is 556m.)

4.4.3.4 Note that B-RNAV requirements for GPS navigation already dictate that the flight crew should carry out a pre-flight RAIM check if there are 23 or fewer satellites in the GPS constellation, which is not the case at present. In any event, the usefulness of such a check is questionable as antenna reception characteristics are not taken into account (see [8]).

Case 2: RAIM limit exceeded (crew aware)

4.4.3.5 Analysing historical data from FAA's GPS performance analysis and applying error characteristics applicable to an airborne GPS receiver, [10] shows that the likelihood of a position error of more than 1 NM is smaller than 10^{-7}.

4.4.3.6 Previous studies carried out for the CAA ([9]) have also identified singular errors that have occurred within the GPS system. However, the large majority of these would not be of sufficient magnitude to exceed the RAIM limits. Additionally, many of the error events recorded were also associated with previous-generation GPS satellites that have since been replaced.

4.4.3.7 This case is assigned a probability of REMOTE.

Case 3: RAIM limit exceeded/RAIM failure (crew unaware)

4.4.3.8 This event occurs either because of a failure in the GPS signals-in-space which is not detected and announced to the crew by the receiver (through RAIM or otherwise), or because of an unannounced failure of the GPS receiver. Note that although the crew are unaware of the initial failure, they may detect the failure later.

4.4.3.9 The MORs in Annex B show only one receiver failure which was not announced to the crew (see incident on 16/02/1999 in Table 19 in Annex B) which suggests an integrity failure rate of order 10^{-5}. This rate is used here, although further validation of this figure is recommended.

4.4.3.10 Unannounced GPS signal-in-space errors are those that would occur and which RAIM or other integrity assurance measures would not detect. TSO-C129a GPS receivers are designed to detect 99.9% of all significant satellite failures. Therefore they would miss 1×10^{-3}. However, significant satellite failures are themselves infrequent. It is assumed that undetected GPS signal in space errors are infrequent compared with the receiver failure rate shown above.

4.4.3.11 Within EFIS, the probability of occurrence is estimated by combining together multiple probabilities as shown in Table 13.

Table 13 Probability analysis for Conflict Scenario 3, Case 3

Event	**Chain of events required**	**Probability (per flight hour)**
A1) A conflict with another aircraft while crossing HMR	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	1×10^{-5} 1×10^{-1} (note 1) 1 (note 2) 1×10^{-3} (note 3) 1×10^{-2} (note 7) **Total: 1×10^{-11}** LESS THAN EX. IMPROBABLE
A2) A conflict with another aircraft while flying same direction on incorrect HMR	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	1×10^{-5} 1×10^{-1} (note 1) 1 (note 2) 1×10^{-1} (note 3) 1×10^{-2} (note 7) **Total: 1×10^{-9}** EX. IMPROBABLE
A3) A conflict with another aircraft while flying opposite direction on incorrect HMR	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Another aircraft in the vicinity without vertical separation AND Flight crew fail to see and avoid other helicopter	1×10^{-5} 1×10^{-1} (note 1) 1 (note 2) 1×10^{-4} (note 3) 1×10^{-2} (note 7) **Total: 1×10^{-12}** LESS THAN EX. IMPROBABLE
B) Wrong information provided to SAR in case of helicopter ditching	Unannounced GPS receiver error causes deviation from intended path AND Flight crew fails to detect and rectify AND ATC fails to detect and rectify AND Helicopter ditches AND ELT not deployed or fails	1×10^{-5} 1×10^{-1} (note 1) 1 (note 2) 1×10^{-5} (note 4) 1×10^{-1} (note 5) **Total: 1×10^{-12}** LESS THAN EX. IMPROBABLE

Table 13 Probability analysis for Conflict Scenario 3, Case 3 (Cont.)

Event	Chain of events required	Probability (per flight hour)
C) Aircrew unable to find an airport or helideck to land	Unannounced GPS receiver error causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-1} (note 1)
	ATC fails to detect and rectify AND	1 (note 2)
	Helicopter unable to find any suitable landing zone before fuel runs out	1×10^{-5} (note 6)
		Total: 1×10^{-11} LESS THAN EX. IMPROBABLE

Note 1: Assumed - see 4.2.3.6. Additionally, it is assumed that flight crew are less likely to detect a deviation if they are presented with erroneous position information as well.
Note 2: It is assumed that ATC does not detect the error until the next position report.
Note 3: See Annex D for collision risk in the case of crossing tracks and flying in the same or opposite direction along an HMR.
Note 4: Assumed - see 4.2.3.8.
Note 5: Assumed - see 4.2.3.9.
Note 6: Assumed, however it is noted that a thousand times increase in the assumed probability of this event will not affect the criticality of the failure, the failure rate staying within 'acceptable' limits.
Note 7: Assumed - see 4.2.3.7..

4.4.3.12 Within (M)RAS/RIS, the availability of ATC radar improves the chances of ATC detection.

Case 4: Position estimate is not available

4.4.3.13 For individual aircraft, the probability of equipment failure is estimated at PROBABLE, based on the analysis in Annex B. Note that NATS staff informally reported a higher failure than that shown by MORs and therefore a check of statistics with NATS staff is recommended.

4.4.3.14 According to the GPS Standard Performance Service (SPS) [13], availability is maintained at or above 99.97% (global average with a 500 metre not-to-be-exceeded predictable horizontal error reliability threshold). This translates to a probability of GPS service unavailability of 3×10^{-4}, i.e. PROBABLE.

4.4.3.15 However, operators did not report any instances of a total failure of the GPS system or of widespread reductions in GPS performance. Hence GPS to date appears to significantly exceed the SPS standard. It is also noted that GPS is operating above its minimum performance requirement in terms of number of satellites and transmission power.

4.4.3.16 Note also that achieved availability by helicopters may be lower than the SPS predicts. CAA research [8] has concluded that, although shielding by rotors does not affect the range measurement accuracy, a reduction in range measurement availability was seen when the GPS antenna was mounted next to the tail rotor. No such reduction in availability was seen with the antenna mounted beneath the main rotor. However, the study did conclude that future changes in the GPS constellation or the reduction in transmission power could result in further reduction in navigation availability when rotor interference is present. A programme of continuous monitoring of GPS availability (as already recommended in paragraph 7.2.2 of the main report) is therefore recommended. This issue also calls into question the suitability of (fixed wing) RAIM prediction algorithms for helicopter operations. This may have to be further investigated if operational monitoring shows that RAIM unavailability is significant.

4.4.3.17 A failure of the entire GPS constellation would result in all aircraft simultaneously losing their GPS navigation capability. This may place additional workload on ATC. While informal discussions did not show any concern here, it is recommended that procedures in the event of total GPS failure are reviewed with NATS.

4.4.4 Risk tolerability

4.4.4.1 Table 14 shows a summary of conflict scenario 3, using the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 14 Summary of Conflict Scenario 3

Conflict Scenario 3: Incorrect position estimation causes deviation from intended path			
	Severity	**Probability**	**Result**
Case 1: RAIM unavailable (crew aware)	MINOR	REMOTE	NEGLIGIBLE
Case 2: RAIM limit exceeded (crew aware)	MINOR	REMOTE	NEGLIGIBLE
Case 3: RAIM limit exceeded/RAIM failure (crew unaware)	Within (M)RAS/RIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) EX. IMPROBABLE A2) EX. IMPROBABLE A3) EX. IMPROBABLE B) EX. IMPROBABLE C) EX. IMPROBABLE	A1) NEGLIGIBLE A2) NEGLIGIBLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) EX. IMPROBABLE A2) EX. IMPROBABLE A3) EX. IMPROBABLE B) EX. IMPROBABLE C) EX. IMPROBABLE	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Case 4: Position estimate is not available	Within (M)RAS/RIS: MINOR	PROBABLE	TOLERABLE
	Within EFIS: MINOR	PROBABLE	TOLERABLE

4.4.4.2 As for conflict scenario 1, one case (Case 3, A2 within EFIS) results in a TOLERABLE risk. In order to mitigate against this risk, the following actions are recommended:

- When leaving radar coverage at approximately 80 NM, the pilot should verify with the ATC that the helicopter is on the correct HMR or, if flying direct, that the helicopter is proceeding on the correct track to the destination. In both cases the heading should be recorded.
- At regular intervals the pilot should check that the heading remains stable. If VOR is available the GPS track can be cross-checked against the pre-determined VOR radial.

In this way, a GPS fault which caused a deviation from the correct track should quickly be spotted through an unexpected heading change.

4.4.5 Applicability to southern North Sea

4.4.5.1 The above analysis was carried out for the operational environment that exists in the northern North Sea. In particular, it takes into account the following:

- Traffic density.
- Radar and communications coverage.
- Route structure.

4.4.5.2 The southern North Sea, however, is characterised by a different operational environment, and the differences have to be considered when analysing the applicability of the hazard analysis.

4.4.5.3 The route structure in the southern North Sea is more complex, primarily because there are three airports in the area compared to one (Aberdeen) in the northern North Sea.

4.4.5.4 The traffic density in the southern North Sea is much higher than in the northern North Sea. In terms of helicopter traffic, the northern North Sea has around 3000 movements per month, while the southern North Sea has around 2000 per month. However, in the southern North Sea, the area containing most of the installations is much smaller than in the northern North Sea, hence the traffic density is greater.

4.4.5.5 However, the most significant difference between the two areas is radar coverage. In the northern North Sea, radar coverage extends to approximately 80 NM from Aberdeen. All HMRs stretch beyond this limit, and most of the installations are located outside this area.

4.4.5.6 In contrast, all but one of the HMRs (HMR 2) in the southern North Sea are under radar coverage. As stated in section 4.2.3.10, ATC monitoring within a RAS/RIS area is a significant mitigation for the identified events.

4.4.5.7 The probability of unsuccessful ATC detection is assumed at 10^{-3} to 10^{-4} [11]. Without even considering the probabilities of other aircraft being in the vicinity, it can be seen by inspection, that by introducing this mitigation, the probabilities for all identified events are reduced to EXTREMELY IMPROBABLE ($<1 \times 10^{-9}$). In this way, all events will have a risk tolerability of at least TOLERABLE. Table 15 below illustrates the calculation for the first event for each of the three conflict scenarios. However, the same value also applies for all the other events for each of the three conflict scenarios.

Table 15 Probability classification for the southern North Sea

Event	**Chain of events required**	**Probability (per flight hour)**
CS1: A conflict with another aircraft	Incorrect flight crew route selection/database checking causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to notice AND	1×10^{-2} (note 1)
	ATC fails to notice and rectify AND	1×10^{-3} (note 2)
	Another aircraft in the vicinity without vertical separation AND	Not calculated
	Flight crew fail to see and avoid other helicopter	1×10^{-2} (note 3)
		Total: $<1 \times 10^{-12}$ LESS THAN EX. IMPROBABLE

Table 15 Probability classification for the southern North Sea (Cont.)

Event	Chain of events required	Probability (per flight hour)
CS2: A conflict with another aircraft	Incorrect aeronautical data causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1×10^{-3} (note 2)
	Another aircraft in the vicinity without vertical separation AND	Not calculated
	Flight crew fail to see and avoid other helicopter	1×10^{-2} (note 3)
		Total: <1.0 x 10^{-12} LESS THAN EX. IMPROBABLE
CS3: A conflict with another aircraft	Unannounced GPS receiver error causes deviation from intended path AND	1×10^{-5}
	Flight crew fails to detect and rectify AND	1×10^{-2} (note 1)
	ATC fails to detect and rectify AND	1×10^{-3} (note 2)
	Another aircraft in the vicinity without vertical separation AND	Not calculated
	Flight crew fail to see and avoid other helicopter	1×10^{-2} (note 3)
		Total: <1.0 x 10^{-12} LESS THAN EX. IMPROBABLE

Note 1: Assumed - see 4.2.3.6.
Note 2: The probability of unsuccessful ATC detection in RAS/RIS area is assumed at 10^{-3} to 10^{-4} [11]. The value used here is the worst case of 10^{-3}.
Note 3: Assumed - see 4.2.3.7.

4.4.5.8 In order to manage the risk of conflict with another aircraft on the part of HMR 2 that is not under radar cover, it is proposed that procedures are specified to prevent the possibility of conflict. These may include providing procedural separations to aircraft flying out on the HMR past radar coverage, and advising aircraft taking off from installations and returning on the HMR of traffic both inbound and outbound.

5 Miscellaneous issues

5.1 Introduction

5.1.1 During discussions with operators and NATS, several specific issues have arisen regarding the en-route procedures adopted in the North Sea. This section presents those issues.

5.2 The suitability of B-RNAV navigational accuracy

5.2.1 The procedures covering equipment installation, approval, operation and maintenance are the same as those for B-RNAV equipment (i.e. JAA AMJ GAI-20 ACJ 20X4).

5.2.2 B-RNAV navigation accuracy (5 NM 95%) appears to be insufficient for maintaining lateral separation on the HMRs. At 80 NM from Aberdeen, the HMR spacing is about 4 NM. A helicopter flying to B-RNAV accuracy could therefore be on the wrong track while still within the specified accuracy, although vertical separation would still be present. This appears to raise a question about the suitability of the B-RNAV standard.

5.2.3 However, aircraft flying with this accuracy are in fact expected to significantly exceed the B-RNAV navigation requirements. This is discussed in Annex D. Hence it would be more appropriate to refer to the relevant equipment requirements, etc. but not refer to 'B-RNAV' which implies a navigational accuracy of 5 NM.

5.3 Operator procedures

5.3.1 There may be some inconsistency or confusion amongst helicopter operators regarding procedures. For example, early guidance material recommended that a regular cross check of GPS position against a manual dead reckoning (DR) plot should be maintained at intervals not exceeding 15 minutes. This procedure was not mentioned by operators, does not appear to be required by the CAA any more and, in fact, is not practical as wind information is provided by GPS.

5.3.2 It may be beneficial to review all of the procedures (those currently undertaken and any new ones proposed as a result of this study) with the operators. A list of procedures is given in Section 6.3.

5.4 Military aircraft

5.4.1 There are several areas of military airspace known as Managed Danger Areas (MDAs). These are above the HMR structure, with a lower altitude of 5,000 ft. However, NATS have reported that it is common practice for the military to operate both within and below the MDAs.

5.4.2 It is recommended that the CAA monitors the proximity of military aircraft as they could cause a hazard to helicopters on the HMRs.

5.5 Alignment of HMRs and VOR radials

5.5.1 Originally, HMRs were aligned with the ADN VOR radials. However, because of a gradual shift in magnetic north, HMRs became offset from the VOR radials by about 1.5 degrees. This caused confusion amongst aircrew, who often reported crossing an HMR when in fact crossing a VOR radial. To alleviate this situation, HMRs were recently re-numbered, so that each HMR is now offset by less than 0.5 degrees from the VOR radial of the same number.

6 Conclusions and recommendations

6.1 Introduction

6.1.1 This section has examined the main hazards arising from the use of GPS for en-route navigation by offshore helicopters.

6.2 Summary of conflict scenarios

6.2.1 Table 16 gives a summary of the conflict scenarios, assuming that the additional procedures proposed in Section 4.2.4.3 are applied for conflict scenarios 1 and 2, namely:

- A procedure should be defined to delete out-of-date temporary waypoints from the RNAV database.

- A manual cross-check of each temporary waypoint against known data should be conducted (e.g. range/bearing from a known point).
- A position report to ATC when joining an HMR outside radar coverage should be made.

6.2.2 Each of the scenarios results in a TOLERABLE risk at most.

6.2.3 Similarly, assuming that the additional procedures proposed in Section 4.4.4.2 are applied for conflict scenario 3, namely:

- When leaving radar coverage at approximately 80 NM, the pilot should verify with ATC that the helicopter is on the correct HMR or, if flying direct, that the helicopter is proceeding on the correct track to the destination. In both cases the heading should be recorded.
- At regular intervals the pilot should check that the heading remains stable. If VOR is available the GPS track can be cross-checked against the pre-determined VOR radial.

6.2.4 Scenario 3 results in a TOLERABLE risk at most.

6.2.5 The scenarios in Table 16 below describe both GPS and non-GPS navigation risks. The highest severity scenarios are all caused by an un-announced deviation from the intended route. This can be because of, for example, GPS failure, an error when programming the RNAV computer, or an error in the navigation database

Table 16 Summary of Conflict Scenarios

	Severity	Probability	Result
Conflict Scenario 1: Incorrect flight crew route selection/database checking causes deviation from intended path			
Undetected selection error leads to helicopter flying the wrong route	Within (M)RAS/RIS: A) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Conflict Scenario 2: Incorrect aeronautical data causes deviation from intended path			
The use of bad aeronautical data leads to a track deviation	Within (M)RAS/RIS: A) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) LESS THAN EX. I. A2) EX. IMPROBABLE A3) LESS THAN EX. I. B) LESS THAN EX. I. C) LESS THAN EX. I.	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Conflict Scenario 3: Incorrect position estimation causes deviation from intended path			
Case 1: RAIM unavailable (crew aware)	MINOR	REMOTE	NEGLIGIBLE
Case 2: RAIM limit exceeded (crew aware)	MINOR	REMOTE	NEGLIGIBLE
Case 3: RAIM limit exceeded/RAIM failure (crew unaware)	Within (M)RAS/RIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) EX. IMPROBABLE A2) EX. IMPROBABLE A3) EX. IMPROBABLE B) EX. IMPROBABLE C) EX. IMPROBABLE	A1) NEGLIGIBLE A2) NEGLIGIBLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
	Within EFIS: A1) CATASTROPHIC A2) CATASTROPHIC A3) CATASTROPHIC B) HAZARDOUS C) HAZARDOUS	A1) EX. IMPROBABLE A2) EX. IMPROBABLE A3) EX. IMPROBABLE B) EX. IMPROBABLE C) EX. IMPROBABLE	A1) NEGLIGIBLE A2) TOLERABLE A3) NEGLIGIBLE B) NEGLIGIBLE C) NEGLIGIBLE
Case 4: Position estimate is not available	Within (M)RAS/RIS: MINOR	PROBABLE	TOLERABLE
	Within EFIS: MINOR	PROBABLE	TOLERABLE

6.3 Summary of procedures

6.3.1 The following table shows the current and proposed procedures that are recommended to mitigate against GPS and navigation failures. The analysis in this report has assumed that 'current' actions are consistently applied by all operators, but if this is not the case then the conclusions would be invalidated. It is recommended that a reviewed list of procedures should be discussed with the helicopter operators and NATS for their agreement and incorporation into relevant manuals.

A number of the proposed procedures have been additionally labelled as "Essential". Essential procedures must be implemented in order to ensure that all risks identified in this study do not exceed TOLERABLE level, as explained in 6.2.1.

Table 17 Summary of GPS/navigation failure mitigation procedures

Action	Current/ Proposed	Comments
Normal operation		
RAIM check pre-flight.	Current (Essential)	Required if there are 23 or fewer satellites in GPS constellation. Value to helicopter operations may be questionable since these requirements designed for fixed-wing operations.
Aircrew cross-check entry of temporary waypoints.	Current (Essential)	
Navigation database is updated each AIRAC cycle.	Current (Essential)	
CDI is set to 1 NM full scale deflection.	Current (Essential)	Impacts on navigation flight technical error. Some RNAV systems may default to 5 NM.
Regular cross-checks (e.g. fuel remaining).	Current (Essential)	Checks required every 20 minutes operators' operations manual.
Aircrew report position when in EFIS.	Current (Essential)	Report rate of 15 minutes maximum is primarily driven by SAR alerting requirements. This would only allow ATC to detect gross errors.
ATC pass information on conflicting traffic.	Current (Essential)	Separation remains aircrew responsibility.
Clear out-of-date temporary waypoints from data base at regular intervals.	Proposed (Essential)	
Aircrew cross-check all entered temporary waypoints.	Proposed (Essential)	For example, a range/bearing check against a known feature/landmark.
Aircrew verify correct heading before leaving radar coverage.	Proposed (Essential)	This applies equally to helicopter flying on an HMR or direct to the destination.
Aircrew periodically perform gross-error check that the expected heading is maintained.	Proposed (Essential)	This applies equally to helicopter flying on an HMR or direct to the destination. Where there is VOR reception, the VOR could be used to cross check against the GPS track. Note that wind can change significantly anyway, so this is only a gross-error check.
All inter-installation traffic separated vertically from HMR traffic where possible.	Proposed	Presently some inter-installation traffic flies at same altitudes as HMR traffic. It would be prudent to ensure that all inter-installation traffic remains separated from HMR traffic. It is understood that this may not be possible under certain meteorological conditions.

Table 17 Summary of GPS/navigation failure mitigation procedures (Cont.)

Action	Current/ Proposed	Comments
Normal operation (continued)		
HOMP monitoring of RAIM if and where practical.	Proposed	Will provide quantitative data on GPS availability and enable GPS performance to be monitored.
Position report to ATC when joining an HMR outside of radar coverage.	Proposed (Essential)	To detect if helicopter has joined the wrong HMR.
Conduct monitoring of GPS navigation equipment reliability.	Proposed	Operators could maintain records of GPS receiver problems/failures.
Undertake regular cross-checks against alternative navigation sources (see Section 4.2.4.2) when outside VHF coverage or any other times when risks may be increased.	Proposed	
Regular review of operations.	Proposed	ATC, operators, military and CAA together to review statistics and changes in GPS, traffic levels, etc. Also opportunity to review procedures.
RAIM lost or exceeded		
Aircrew report to ATC.	Current (Essential)	Time waited before contacting ATC may not be consistent. It is proposed to standardise on, e.g. 2 mins.
ATC widens the parameters within which traffic information is passed for EFIS.	Current (Essential)	At discretion of ATC.
Cross-check against whichever other navigation sources available.	Current (Essential)	Subject to availability of alternative external navigation aids.
GPS unserviceable or navigation equipment failure		
Aircrew report to ATC.	Current (Essential)	Time waited before contacting ATC may not be consistent.
ATC widens the parameters within which traffic information is passed for EFIS.	Current (Essential)	At discretion of ATC.
Alternative navigation, e.g. DR or NDB where reception possible.	Current (Essential)	Subject to availability of alternative navigation source.
ATC procedures for wide area loss of GPS.	Proposed	ATC should have contingency procedures in the event that GPS is lost to multiple helicopters in the North Sea.
Aircrew request NDB at destination installation to be activated.	Proposed	Provides assistance in case of navigation failure.
If failure occures on installation before take-off, inform ATC.	Proposed	Allows ATC to check the traffic density around return route is low before departure.

6.4 Recommendations

6.4.1 Procedures

- CAA should discuss the procedures detailed here with the helicopter operators and NATS with a view to incorporating them into relevant manuals and training material as appropriate (see 6.3.1).
- CAA should discuss the mitigations proposed in 4.2.4.3 with the helicopter operators to confirm that they are practical and acceptable. Further ideas for mitigations should also be sought from the helicopter operators.
- The helicopter operators should standardise their procedures, particularly those for contacting ATC in the event of a longer (more than a few seconds) RAIM outage (see 4.4.2.3).
- CAA should discuss with ATC what procedures, if any, are appropriate to cater for the event of a wide-area GPS failure (see 4.4.2.14 and 4.4.3.17).
- CAA and NATS should establish additional procedures for avoiding conflicts on the part of HMR 2 in the southern North Sea that is not under radar cover (see 4.4.5.8).

6.4.2 Monitoring

- CAA should consider creating a forum for regularly reviewing statistics and procedures with ATC, the helicopter operators and the military. This would allow discussion of the performance of GPS (e.g. monitored using HOMP), the impact of changes in operations (e.g. new military areas), and to ensure that all procedures are being consistently applied.
- The helicopter operators should monitor GPS RAIM availability on a regular basis to detect any variations in GPS performance that might impact on GPS-based North Sea helicopter operations (see 4.4.3.16). This is consistent with ICAO recommendations and might conveniently be achieved using HOMP.

6.4.3 Investigations

- CAA should investigate the effectiveness of RAIM prediction algorithms if monitoring shows that RAIM outages in the North Sea are significant (see 4.4.3.16). Data from RAIM predictions should be compared to actual RAIM outages (measured by the helicopter operations monitoring programme, HOMP). In the long term, RAIM prediction algorithms may have to be modified to make them more suitable for helicopter operations.
- In conjunction with the helicopter operators, CAA should collect statistics on RAIM availability to validate the assumption that significant RAIM outages do not occur in the North Sea (see 4.4.3.1). This might conveniently be achieved through HOMP.
- The unannounced GPS receiver failure rate (integrity failure), taken as 10^{-5}, should be validated by the helicopter operators (see 4.4.3.9).
- NATS should establish aircraft equipment failure rates from their records in order to confirm the assumptions made in this hazard analysis (see 4.4.3.13).
- CAA should validate the numbers assigned to probabilities for the events listed in Table 7, Table 10 and Table 13.

7 References

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Part 1, Annex A Functional Analysis

A.1 Introduction

A.1.1 This Annex contains a functional architecture of the aircraft navigation systems which is used to identify hazards that could occur. The resulting detailed hazard list was used to help identify the top-level hazards which were given in Section 3.

A.2 Functional architecture

A.2.1 Figure 1 shows a functional architecture of the helicopter and other systems.

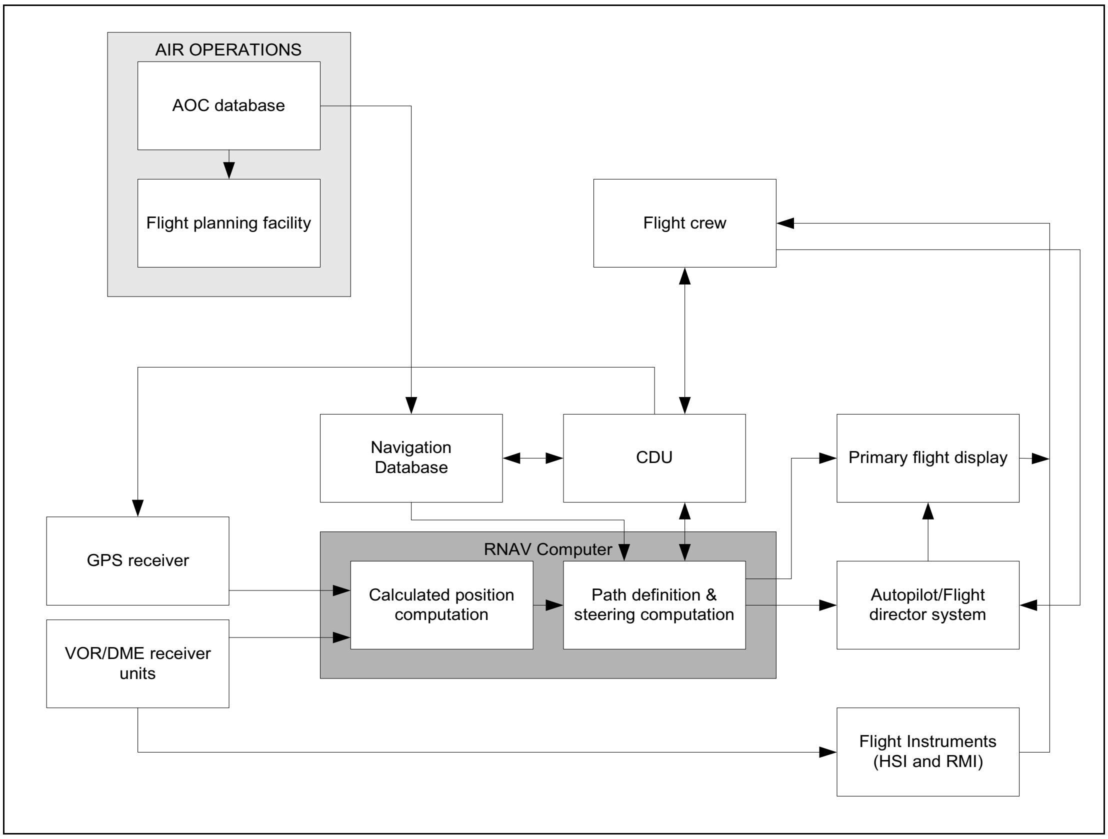

Figure 1 Helicopter system architecture

A.2.2 The following guidance is provided to help the reader interpret the diagram.

A.2.3 North Sea helicopters are equipped with both GPS and VOR/DME receiver units. The RNAV computer, depending on the type fitted, takes position information from either one or both of the sensors:

- The first type allows for RNAV navigation based on GPS position only (specific systems include the Bendix King KLN 90B and the Free Flight 2101).
- A number of helicopters use the RNAV-2 computer (from Thales), which allows RNAV navigation based on VOR/DME as well as GPS.

A.2.4 The RNAV computer takes information from the navigation database, including:

- Positions of aerodromes and fixed installations together with approach fixes;
- HMRs and waypoints;
- SIDs and STARs.

A.2.5 The navigation database is produced for the operators by one of a number of suppliers. The operators may then amend or add waypoints to the database before it is uploaded to individual helicopters.

A.2.6 The flight crew interact with the RNAV computer and the navigation database via the Control Display Unit (CDU). They are able to select waypoints, routes, SIDs and STARs from the database to make up a route to be flown.

A.2.7 Flight guidance is provided from the RNAV computer via the primary flight display. Information from the VOR/DME receivers is also displayed to the crew via the flight instruments.

A.3 Potential hazards

A.3.1 The following table lists all the interfaces between components in the system in terms of potential risks, and summarises the reasons for/against inclusion in the hazard assessment.

Table 1 Functional hazards

Interface		Potential hazard	Included in analysis as top-level hazard?
From	**To**		
AOC database	Navigation database	Erroneous data in database. Database is out of date.	Yes, included in Hazards ID1 and ID2
Autopilot/Flight director system	Primary flight display	Wrong or missing information provided form flight director system.	No, not specific to GPS operations
Calculated position computation	Path definition & steering computation	Wrong or missing data provided to the path definition and steering computation function.	No, not specific to GPS operations
CDU	Navigation database	Unable to access database. Wrong data passed to database.	No, not specific to GPS operations
CDU	GPS receiver	Unable to access GPS from the CDU.	Yes, included in ID4.
CDU	Path definition & steering computation	Unable to access steering information.	No, not specific to GPS operations
CDU	Flight crew	Display failure.	No, not specific to GPS operations
Flight crew	CDU	Flight crew selects wrong data.	Yes, included in ID3.
Flight Instruments (HSI and RMI)	Flight crew	Flight crew get wrong/ missing information from flight instruments.	No, not specific to GPS operations
GPS receiver	Calculated position computation	GPS provides erroneous data to RNAV computer. GPS data missing.	Yes, included in ID4 and ID5.

Table 1 Functional hazards (Continued)

Interface		Potential hazard	Included in analysis as top-level hazard?
From	**To**		
Navigation database	CDU	Erroneous or missing data from the navigation database presented to crew on CDU.	Yes, included in ID4 and ID5.
Navigation database	Path definition & Steering computation	Erroneous or missing data from the navigation database provided to RNAV computer.	Yes, included in ID4 and ID5.
Path definition & Steering computation	CDU	Wrong or no path information passed to CDU.	No, not specific to GPS operations
Path definition & Steering computation	Autopilot/Flight director system	Wrong or no path passed to autoflight system.	No, not specific to GPS operations
Path definition & Steering computation	Primary flight display	Wrong or no path displayed to crew.	No, not specific to GPS operations
VOR/DME receivers	Calculated position computation	Erroneous or missing position information from VOR/DME provided to RNAV computer.	No, not specific to GPS operations
VOR/DME receivers	Flight Instruments (HSI and RMI)	Erroneous or missing position information from VOR/DME receivers presented on flight instruments.	No, not specific to GPS operations

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Part 1, Annex B Analysis of MORs

B.1 Introduction

B.1.1 This section contains an analysis of formal CAA Mandatory Occurrence Report (MOR) summaries. It shows the MORs that highlight a failure of GNSS/GPS or navigation databases.

B.1.2 The MOR scheme covers:

- Any aircraft operated under an air operator's certificate granted by the CAA.
- Any turbine-powered aircraft which has a certificate of airworthiness issued by the CAA.

B.1.3 The MOR scheme is used to report any incident which endangers or which, if not corrected, would endanger an aircraft, its occupants or any other person.

B.1.4 The statistics shown should be treated as indicative since some failures may be innocently reported as a different type of failure.

B.2 Functional architecture

B.2.1 The database extract was made based on the criteria of "twin turbine helicopter incidents involving GPS or the navigation database." They cover both on-shore and off-shore operations and include reports up to the end of July 2008.

B.2.2 Some of the reports are caused by failures of other equipment (e.g. ADF), or in areas away from the North Sea and these are listed in separate tables.

Table 1 RNAV/GPS-related MORs in North Sea

Date	Location	Description
03/06/1985	North Sea	GPS unit failed to navigate 30 minutes into flight. Loose mounting rack suspected.
16/07/1993	North Sea	RNAV 'no ident' track error increased, despite position track update.
24/04/1996	North Sea	On approach, RNAV showed incorrect position. ADF continually showed rig in 12 o'clock position even after aircraft had passed rig.
20/05/1997	North Sea	GPS display froze in cruise.
13/07/1997	North Sea	GPS failure with "database missing" and "GPS receiver fail, battery backup fail" messages.
01/09/1998	North Sea	GPS screen blank; software upgraded in Trimble[1] GPS equipment.
26/10/1998	North Sea	RNAV unit failure; not clear if GPS equipment failure had occurred.
16/02/1999	North Sea	GPS equipment failure; gave undetected error of 8 NM; no warning indications; GPS receiver changed.
27/09/1999	Offshore Installation	RNAV-indicated wind may have been in error; not clear if GPS or RNAV equipment fault occurred.
05/12/2000	En-route	GPS equipment did not update position; caused by incorrect installation.
28/12/2000	North Sea	GPS position stopped updating; indicated to crew through HSI 'off' flag.

Table 1 RNAV/GPS-related MORs in North Sea (Continued)

Date	Location	Description
23/01/2001	North Sea	GPS 'froze' and started listing names; caused by out-of-date Jeppesen card.
12/04/2001	North Sea	'Total' RNAV equipment failure.
18/04/2001	North Sea	HSI 'off' flag shown and CDI 'froze'; cause not clear, but investigation highlighted need to ensure good procedures for managing database cards.
16/07/2001	North Sea	GPS display blank; operating software re-loaded to fix; Reporter comments system "very unreliable" and suspects GPS database.
06/06/2002	North Sea	GPS failed 'performing initial test'; equipment indicated position of North Pole; no fault found but problem cleared after software re-load.
26/06/2002	North Sea	'RAIM unavailable' (with associated HSI 'off' flag) for most of flight; other aircraft not affected; GPS RDU replaced..
15/07/2003	Aberdeen	Smoke and strong smell of burning from GPS unit. Fault traced to GPS receiver.
10/01/2005	North Sea	Incorrect position information from GPS unit. Cleared by switching off and on receiver.
20/01/2005	North Sea	'RNAV off' warning and RNAV coupling disengaged while en-route. Followed by 'RAIM unavailable' indication.
01/02/2005	North Sea	GPS failed, providing no output.
11/11/2005	En-route	Loss of GPS signal. Intermittent loss for long periods then continuous loss of RAIM.

1. Trimble have since become Free Flight.

Table 2 MORs extracted from same report. In North Sea region but not directly GPS-caused

Date	Location	Description
12/12/1996	Omeath 2se	Fatal CFIT during GPS non-precision approach. (No GPS errors identified)
10/07/1997	Not known	GPS malfunction - heading and TAS data not picked up by GPS. All other data defaulted to preset "factory conditions"
04/11/1997	North Sea	Aircraft off track on first contact with FIR controller.
05/12/2001	Offshore installation	Damage to antenna noticed during external inspection. Reported had previously noted frequent RNAV failures.
22/01/2002	North Sea	Lightning strike caused GPS failure.
07/01/2003	Northampton	Garmin nav/comm. receiver failed causing loss of GPS power supply.
06/07/2003	Chipping	UK airprox between glider and helicopter. Helicopter was flying a direct track programmed into the GPS.
01/08/2002	North Sea	Various electrical failures on two consecutive days.

Table 2 MORs extracted from same report. In North Sea region but not directly GPS-caused (Continued)

06/09/2002	Sumburgh	DC fail with loss of multiple systems.
Date	**Location**	**Description**
02/09/2003	En route	Battery generator failure. Multiple equipment/indication failures.
13/09/2005	Not known	GPS failed soon after take off.
18/05/2005	En route	Uncommanded collective input, while using upper modes NAV/VS.
25/05/2005	Aberdeen	Flight director command bar anomaly.
03/03/2006	North Sea	Lightning strike caused temporary instrument and navigation system failures.
28/06/2006	Sumburgh	Cleared altitude exceeded by 800 ft during climb out. Pilots distracted by need to re-programme RNAV after realising that destination rig position was grossly in error.
06/02/2007	Aberdeen	Lightning strike rendered GPS inoperative.
20/05/2007	North Sea	NAV switching/selector panel changed to emergency mode during flight.

Table 3 Other MORS extracted from same report

Date	**Location**	**Description**
06/10/1986	Blackbushe	Newly installed RNAV gave recersed cross-track deviation.
22/02/1999	Peterhead	Aircraft struck by lightning. GPS rendered inoperative.
03/12/2000	Newcastle	"White noise" on number 2 communications box. Problem "appears related to FLIR and Skyforce GPS system".
20/12/2000	Aberdeen	Indicator failure on ILS approach. Problem thought to be related to modification made to enable presentation of GPS steer information on the HSIs.
03/08/2003	Talla	Loss of 2 GPS signals in independent GPS units. No cause (e.g. jamming) identified.
19/09/2003	Stansted	ATC unable to establish contact with police EC-135. Contributed by lack of GPS-system with map overlay available to pilot.
16/03/2005	Eskmeals	Infringement of MOD danger area. Pilot realised infringement when he consulted GPS.
13/11/2005	Manchester	GPS receiver failed on start up.
17/03/2006	Dublin	Infringements of Dublin Control Zone caused by use of FMS database that contained errors.
24/04/2006	London City	Infringement of London City CTA due to overreliance on GPS (which included out of date information).
16/05/2007	Not known	Uncommanded disengagement of NAV hold function, twice during cruise.
22/09/2007	North Denes	RNAV failure during taxi out.

B.2.3 Estimates of the incident rates based on this data are given in the following table.

Table 4 Estimated incident rates - indicative only

Type of MOR	**Period of reporting**	**Estimated round-trips numbers (1)**	**MOR rate per movement**
GPS/nav MORs	May 1998 - July 2008	400, 000	5 x 10^{-5}
(1) Round-trips from Aberdeen shown, but Anglia Radar flights and Sumburgh/Scatsta flights not included			

B.2.4 Due to uncertainty in the statistics used, these figures should be treated as indicative only.

B.2.5 Assuming an average round-trip time of 3 hours flying time (figure to be confirmed), the average GPS/navigation equipment failure rate is 5 x 10^{-5}. This figure suggests an equipment failure probability of PROBABLE (i.e. between 1 x 10^{-3} and 1 x 10^{-5}), notwithstanding the caveats on the accuracy of data.

Part 1, Annex C Risk Register Analysis

C.1 This annex lists the risks identified in earlier CAA work and shows the links to each hazard in this report, where applicable.

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
1. Data					
1.1	3. PRNAV [A.4.17]	VOR/DME sensors require a different database / FMS coding than GNSS - and/or DME/DME based systems		This would greatly expand the volume of detail for both charting and the databases.	N/A
1.2	3. PRNAV [A.4.17]	Misinterpretations and errors during the database coding process		Concerns related to the provision of pre-described coding schemes in the AIP, indicate that adequate training for the procedure designer is required to ensure proper navigation- and FMS-system knowledge, their constraints and the ARINC 424 rules.Additionally, close co-operation between ANSP and the database provider on one hand and the database provider and the database packer on the other hand is urgently required.	ID1

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
1. Data (continued)					
1.3	3. PRNAV [A.4.17]	Database contains errors.	Harmonise standards for database accuracy and integrity and ensure universal application of standards. Individual states need to ensure that survey requirements (including WGS84) have been complied with. States should consider regulating to ensure that database standards are met. Wider aeronautical data comparison activity should be considered. AIPs should provide the ARINC 424 coding to remove ambiguity. This is already in guidance for procedure designers and charting, but needs to be enforced.Database checking procedures should be developed by airlines/ operators and observed problems shared via a centralised AIS system (e.g. EUROCONTROL's AIS AGORA). Develop European AIS Database and ensure data accuracy and integrity.	Assuming the availability of all required tools this issue is sufficiently covered by Guide Doc [A.4.22], ED-76 [A.7.2] and Annex 15 [A.6.5]. Nevertheless, operational experience indicates that daily practice differs significantly. Hence, this item cannot be deemed to be solved in practice and poses a major safety concern. Appropriate training for the procedure designer and the pilot is required in order to ensure compliance with these standards. [Note: JAR 21, Production Organisation Approval procedures, when implemented, will have a significant influence in this area.]	ID1
1.4	3. PRNAV [A.4.17]	Wrong database is used		The interaction between AIRAC and ARINC cycle needs to be improved. It has to be emphasised in particular that procedure changes via NOTAMs after their publication in the AIP may result in database problems. Hence this item is not yet covered.	ID2

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
1. Data (continued)					
1.5	3. PRNAV [A.4.17]	Published information for RNAV procedure, including charting, is incomplete, insufficient or unclear.	A review should be conducted to assess whether there is adequate charting guidance, e.g. identification of RNAV procedure critical navaids, providing the co-ordinates for use of runway intersections and Quick Align points. Consideration should be given to ensuring the harmonisation of charting for RNAV procedures so that controllers and pilots use the same waypoint names.	See 1.2 and 1.3	N/A
1.6	2. NPA [A.2.13]	Lack of database integrity	Certification of database manufacturing process (including ATC, AIS, database suppliers and operators) in accordance with RTCA Do 200A and RTCA Do 201A standards. Continuation of the database check through flight check before authorising public use.		ID1
1.7	2. NPA [A.2.13]	Incorrect coding of waypoint attributes	Certification of database manufacturing process. Continuation of the database check through flight check before authorising public use.		ID1
1.8	1. NPA [A.2.11]	Aircraft course incorrectly defined	Implement standards for database production/management. Conduct test flights using databases. Confirm that the data generation and database production and management provide adequate controls over data quality. Consider introducing checks in pilot and controller procedures. Consider making visual displays such as EFIS mandatory.	No protection against creeping errors if no airfield radar. Database integrity and accuracy critical with GPS, as there is no physical verification of course/position (unlike, say, flying a VOR radial)	ID1

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
1. Data (continued)					
1.9	1. NPA [A.2.11]	Aircraft guided to wrong position (out of date database)	Consider methods of monitoring database validity	Hazard is exacerbated in that pilots will have confidence in their information, even though it may be wrong. More of a problem for GA traffic.	ID2
2. RNAV Procedures, Waypoint Naming and Airspace Design					
2.1	3. PRNAV [A.4.17]	Operational Concept	The EUROCONTROL Guidance Material for the Design of Terminal procedures provides detailed guidance on RNAV but industry's understanding of the subject would be improved if a high level, Operational Concept document were to be produced.	The complexity highlights the distinct need for a sound operational concept for the introduction of RNAV in the TMA with acknowledgement of the actual system capabilities.	N/A
2.2	3. PRNAV [A.4.17]	ATC Operational Perspective	EUROCONTROL may wish to consider updating its document "RNAV Application in Terminal areas - An ATC Operational Perspective, Edition 2D, 22.09.99" to incorporate lessons learned since it was first published.		N/A
9.1	3. PRNAV [A.4.17]	Step-wise introduction of RNAV	RNAV should be introduced in a Step-wise manner, as illustrated in the EUROCONTROL ATC Perspective document, throughout the industry as experience and confidence in procedures is built up.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
2. RNAV Procedures, Waypoint Naming and Airspace Design (continued)					
2.3	3. PRNAV [A.4.17]	Procedures have to be designed for the worst-case scenario of the stated navigation sensors.	Procedure designer training should address the availability, identification and charting of critical navaids.Training with respect to navaid outages and identification of critical navaids should be given to procedure designers and flight planners. ATSPs need to develop, as part of their Safety Management System (SMS), a policy/methodology on how to react to navaid failure, including navaids outside their FIR, or navigation system failure affecting multiple aircraft (e.g. GNSS).	The required tool to determine these worst case stations is not available (a) For VOR in general (b) For DME. (Note: DEMETER is not designed to identify the least performing station.) Clarify the use of Navaids that are outside the managerial control of the ATSP, e.g. military, private or abroad.Clarify the legal status of the use of Navaids outside their designated operating range.	N/A
2.4	3. PRNAV [A.4.17]	PANS OPS [A.6.7] requires a scanning tool and a pre-promulgation flight check for IFR procedures.		PANS OPS [A.6.7] to clarify the intent of the flight check.Ensure availability of the required equipment.	N/A
2.5	3. PRNAV [A.4.17]	ICAO OCP never developed procedure design criteria for INS/IRS.		Guide Doc [A.4.22] needs to clarify the status of INS/IRS with regard to (a) Procedure design; (b) The sole use for TMA RNAV.	N/A
2.6	3. PRNAV [A.4.17]	AIP published procedure is not correct due to publication and/or calculation errors.		The availability of the required tools and appropriate training for procedure designers and pilots is required to ensure compliance with the standards.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
2. RNAV Procedures, Waypoint Naming and Airspace Design (continued)					
2.7	3. PRNAV [A.4.17]	Inconsistency between use of auto flight modes as assumed during procedure design and in practice.	RNAV systems should provide clear mode annunciation as it can vary between different systems. Given that mode confusion has played a part in a number of recorded deviations this is an important issue and any limitations in equipment need to be addressed via procedures and training.Pilot training should address FMS/RNAV capabilities and potential mode selection failure modes.	Corresponding recommendations need to be included into Guide Doc [A.4.22] to bring to the attention of each State's regulator the importance of the required training for pilots in order to maintain the assumptions stipulated in TGL 10 [A.3.4].	N/A
2.8	3. PRNAV [A.4.17]	Procedure complexity	Design RNAV instrument procedures with a minimum number of waypoints consistent with operational requirements.		N/A
2.9	3. PRNAV [A.4.17]	Waypoint naming confusion	Control waypoint naming (prevent duplicates/ similarities/ confusion) - use upgraded ICARD.		ID1
2.10	3. PRNAV [A.4.17]	Use of closed procedures onto final approach	Closed procedures, i.e. automatic turn on to final approach, should receive particular care in their design in order to minimise the opportunity for error. By placing the procedure turn at the furthest downwind point and by providing information to the pilots in the AIP to expect vectors prior to that point, the opportunity for flightdeck confusion and controller error can be reduced.		N/A
2.11	3. PRNAV [A.4.17]	Interaction between procedure design and ATC operations	Procedure designer training should address ATC operational requirements.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
2. RNAV Procedures, Waypoint Naming and Airspace Design (continued)					
2.12	3. PRNAV [A.4.17]	Waypoints and significant points	The relationship between waypoints and significant points, and their status in ATS routes (Area Navigation Routes) should be clarified in ICAO Annex 11 [A.6.3].		N/A
2.13	3. PRNAV [A.4.17]	SID/STAR naming convention	A meaningful, RNAV oriented SID/STAR naming convention should be developed. Note: The ICAO OCP is addressing this issue.		N/A
2.14	3. PRNAV [A.4.17]	Waypoint naming convention	European waypoint naming "convention" should avoid 0s and 5s (some states use 400+). Note: Other conventions may also offer benefits. It is recognised that it is impossible to eliminate possibilities for confusion and that certain error modes may be location specific.		N/A
2.15	2. NPA [A.2.13]	Confusion between GPS waypoints	Procedural design: it is recommended not to publish a stepdown waypoint in the final approach segment as this may lead to confusion on the descent path.Provide adequate training to promote awareness of this potential hazard.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
3. Aircraft systems					
3.1	3. PRNAV [A.4.17]	Aircraft performance does not allow the procedure to be flown (correctly).		Adherence to Guide Doc [A.4.22] ensures that the procedures are fly-able.	N/A
3.2	3. PRNAV [A.4.17]	Coded (database) procedures are flown differently by different Flight Management Systems.	Ensure the compatibility of current standards for FMS/RNAV turn algorithms with P-RNAV airspace and ATC operational requirements. The RNAV procedure guidance material needs to highlight the variation in turn performance possible with P-RNAV certified aircraft. Procedure designer training should address awareness of turn characteristics of aircraft FMS.		N/A
3.3	3. PRNAV [A.4.17]	Different behaviour of Flight Management System in TMA-mode (low altitude) compared to en-route (high altitude), and there is no uniform transition (both ways).	Ensure the compatibility of current standards for FMS/RNAV turn algorithms with P-RNAV airspace and ATC operational requirements. The applicability of current certification standards, particularly in relation to High Altitude Turn Transitions, for FMS should be reviewed given that the transition bi-sector is not defined by any Terminal Airspace procedure limits and could be as low as FL120 in certain circumstances.	Although there is an intermediate solution practicable, the long-term solution requires RF-leg compatible FMSs and ARINC 424 [A.8.3] coding rules, respectively.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
3. Aircraft systems (continued)					
3.4	3. PRNAV [A.4.17]	Varying on-board aircraft systems capabilities.		VOR/DME and INS/IRS can neither be considered to be covered sufficiently by the standards and guideline documents nor it is expected that the open issues may be closed to comply with the TGL 10 [A.3.4] performance requirements. Assuming that all stated open issues and inconsistencies are solved and all required features for DME/DME applications are available, no significant differences between GPS and DME/DME are expected.	N/A
3.5	3. PRNAV [A.4.17]	Harmonisation of TGLs 2 [A.3.1] and 10 [A.3.4].	Consideration should be given to the review and harmonisation of TGLs 2 [A.3.1] and 10 [A.3.4] particularly in respect of training for Flight Crew and airline operations ground staff (and contractors where applicable). Consideration should be given to the review and harmonisation of TGLs 2 [A.3.1] and 10 [A.3.4] in respect of RAIM		N/A
3.6	3. PRNAV [A.4.17]	Variation in aircraft performance (speed, turn radius).		The item is covered by Guide Doc [A.4.22], Section 5.1.6 of [A.4.15], and ARINC 424 [A.8.3], if the RNP path terminators are applied (solely).	N/A
3.7	3. PRNAV [A.4.17]	+/- 1 NM not required for all recognised P-RNAV sensors		TGL 10 [A.3.4] has to highlight that the assumed accuracy is more stringent than the certification requirements in AC 20-130 [A.5.12] and TSO-C115 [A.5.7]. According to item (4) in section 6.1 of TGL 10 [A.3.4], the achievement of the assumed accuracy, i.e. +/-1 NM, has to be demonstrated at certification.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
3. Aircraft systems (continued)					
3.8	3. PRNAV [A.4.17]	VOR/DME criteria are tailored to one specific receiver type.		Do not use PANS OPS [A.6.7] criteria for VOR/DME for TMA RNAV.	N/A
3.9	3. PRNAV [A.4.17]	VOR/DME station mover receivers have never been certified for TMA operations.		TGL 10 [A.3.4] to confirm that VOR/DME station mover receivers are not acceptable for P-RNAV.	N/A
3.10	3. PRNAV [A.4.17]	The radio update point depends on the used positioning sensor.	Runway auto-updating - The introduction of P-RNAV routes flown from the ground could lead to a significant change in position shift events. Consideration should be given to requiring automatic updating; otherwise aircraft should be advised to navigate the initial portion of a route conventionally. This would reduce the opportunities for manual initialisation errors.	A "low cost and safe solution" might be to identify MSA/MRVA as the first radio update point.	N/A
3.11	3. PRNAV [A.4.17]	Wrong selection of DME (by the system).		This item is not considered a safety concern, provided the items identified in 2.3 are solved.	N/A
3.12	3. PRNAV [A.4.17]	Multiple aircraft lose RNAV capability at the same time, for instance after GPS failure or jamming.		ATC needs to be able to comply with its obligation to assess the actual navigation performance for VOR/DME and/or DME/DME based RNAV.	ID5

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
3. Aircraft systems (continued)					
3.13	3. PRNAV [A.4.17]	Poor pilot interface with RNAV system, in particular for general aviation RNAV systems without an alphanumeric keyboard.Flight deck map display to improve situational awarenessEnhancements to map display	Appropriate pilot training is required to cope with the higher complexity of database driven systems.A flight deck map display would significantly aid flight crew situational awareness, however, there could be issues of space, weight and cost for some aircraft types. The introduction of enhancements to flight deck map displays, e.g. display other RNAV routes, would improve flight crew situation awareness. Such enhancements would, however, need careful management in order to prevent the display becoming too cluttered.	Refer to 4.4	N/A
3.14	3. PRNAV [A.4.17]	TGL3 [A.3.2] compliant RNAV systems may not be compatible with ARINC 424 [A.8.3].		If the procedure is designed in accordance with the PANS OPS [A.6.7] criteria for GPS and coded as such, this item does not apply.	N/A
3.15	3. PRNAV [A.4.17]	System redundancy	System redundancy - an assumption in TGL 10 [A.3.4] is that the particular hazards of a TA and the feasibility of contingency procedures following loss of P-RNAV capability are assessed and, where considered necessary, a requirement for the carriage of dual P-RNAV systems is identified in the AIP for specific P-RNAV procedures. The benefits of such a measure will be related to the probability of loss of navigation function. The lower this probability for single systems the lower the benefits of requiring a dual system.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
3. Aircraft systems (continued)					
3.16	3. PRNAV [A.4.17]	Multi-sensor nav capability	A requirement for aircraft to have multi-sensor navigation capability should be considered as this clearly offers benefits from the viewpoint of failures affecting both single and multiple aircraft in the airspace. However, considerations of costs, as well as space and weight on aircraft may render this impractical.		N/A
3.17	3. PRNAV [A.4.17]	Quick align for IRS	Quick Align for IRS - The use of the Quick Align function of IRS could introduce other hazards, such as a pilot failing to switch back to LNAV, therefore, the merits of the use of Quick Align needs further study.		N/A
3.18	3. PRNAV [A.4.17]	Datalink	The increased use of datalink would be a useful safeguard against some of the failure modes related to departure clearance errors. While RNAV introduction is not linked to a requirement for datalink, its benefits in this regard should be noted when it is being considered in a wider context.		N/A
3.19	1. NPA [A.2.11]	Aircraft speed guidance inaccurate (software error in FMC)		Speed data is a problem with some FMSs - speed guidance may not be good enough to follow track on ground accurately. Not new to GPS.	N/A
3.20	1. NPA [A.2.11]	Aircraft ground speed incorrectly calculated (error in GPS signal or software)	Update rate of GPS kit should be fast enough to prevent ground speed errors causing severe course deviations.	No protection against small or creeping errors if no radar.Very little tolerance for errors in the descent rate during phases 3 and 4.	N/A
3.21	1. NPA [A.2.11]	Position data unavailable and speed incorrect	Duplicate air speed sensors and altimeters		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
3. Aircraft systems (continued)					
3.22	1. NPA [A.2.11]	Guidance instructions to pilot or autopilot incorrect (FMC malfunction or incorrectly programmed)	Software design standards and pre-installation testing.Confirm specified integrity appropriate for GPS-based system.		N/A
3.23	1. NPA [A.2.11]	Position errors (Use of uncertified kit or use of GPS on non-GPS approach)		Should not occur, but difficult to regulate GA.	N/A
4. Flightdeck issues					
4.1	3. PRNAV [A.4.17]	Insufficient awareness of P-RNAV performance.		The item could be considered as covered, provided the reliability, responsibility and correctness of the indication of the actual navigation performance / accuracy are verified in the certification process.	N/A
4.2	3. PRNAV [A.4.17]	Loss of pilot situational awareness	A flight deck map display would significantly aid flight crew situational awareness, however, there could be issues of space, weight and cost for some aircraft types.	All items are training issues	N/A
4.3	3. PRNAV [A.4.17]	Clearance to a waypoint outside the normal procedure leads to increased pilot workload and potential for errors.	Pilot training should address use of tactical waypoints and constraints.	Clearances to waypoints that are not charted on the actual procedure chart are not yet covered by the international standards and guideline documents.ICAO PANS OPS Vol. I [A.6.7], ICAO Doc. 4444 [A.6.6] and/or Doc. 7030 [A.6.15] require amendments, accordingly.Appropriate training for procedure designers and close co-ordination between the procedure designer and the database provider / packer and adherence to the ARINC 424 [A.8.3] rules are required.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
4. Flightdeck issues (continued)					
4.4	3. PRNAV [A.4.17]	High pilot workload (head-down time) may cause deviation from RNAV procedure or inability to sustain RNAV navigation		Appropriate pilot training is required to cope with the higher complexity of database driven systems.	N/A
4.5	3. PRNAV [A.4.17]	Proficiency standards for standalone GPS users	Proficiency standards and/or educational material should be considered for stand-alone GPS users (e.g. use of RAIM).		N/A
4.6	3. PRNAV [A.4.17]	General aviation pilot training - little control on standardisation for checking / training in the use of RNAV/GPS equipment and procedures.	An education/monitoring system, suitable for pilots of General Aviation (GA) and aerial work aircraft with an RNAV capability, which, currently, fall outside the TGL training and approval process, needs to be considered.	This item lies within the responsibility of JAA and the national CAAs. Appropriate pilot training is required to cope with the higher complexity of database driven systems.	N/A
4.7	3. PRNAV [A.4.17]	Flight planning	Pilot training should address the implications of not updating the Flight Plan. This will be relevant to pilots of P-RNAV, B-RNAV and non-RNAV equipped aircraft.		N/A
4.8	3. PRNAV [A.4.17]	Runway/ position update	Pilot training should address runway/position updating of INS/IRS.		N/A
4.9	3. PRNAV [A.4.17]	Navaid availability	Pilot training should address navaid unavailability.		N/A
4.10	3. PRNAV [A.4.17]	Contingencies	Pilot training should address contingencies.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
4. Flightdeck issues (continued)					
4.11	3. PRNAV [A.4.17]	Cross checking	Pilot training should address cross checking, where this is possible, against raw navigation data.		N/A
4.12	3. PRNAV [A.4.17]	RT discipline	Pilot training should also address the need to maintain RT discipline. Although not solely a P-RNAV issue, the greater use of alphanumeric identifiers in Tactical Waypoint naming raises the importance of using correct RT, still further.		N/A
4.13	3. PRNAV [A.4.17]	Pilot's actions, when proceeding past the last cleared waypoint, are not clear to the ATCO.		This item poses a major safety concern since it yields to unpredictable aircraft behaviour. It is not yet covered by the international standards and guideline documents.	N/A
4.14	3. PRNAV [A.4.17]	Pilot makes mistake when editing a programmed procedure.	Pilot training should address RNAV system flight plan selection and revision.		ID3
4.15	3. PRNAV [A.4.17]	Flight path deviation due to the use of non-official waypoints.		Appropriate training for pilots is required. This training is specifically important for GA pilots.	ID3
4.16	3. PRNAV [A.4.17]	Pilots make mistake between 'fly over' and 'fly by' waypoint		Appropriate pilot training is required.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
4. Flightdeck issues (continued)					
4.17	3. PRNAV [A.4.17]	Pilot fails to remove FMS database restriction after being cleared for a further level, causing the aircraft to level off.		This item has to be covered by appropriate pilot training.	N/A
4.18	2. NPA [A.2.13]	Inadequate crew training	Provide adequate training for aircrew and ATC controllers. Distribution of information on use of GPS. Availability of translated manuals on how to handle the GPS equipment.		N/A
4.19	2. NPA [A.2.13]	Selection of incorrect GPS approach	Proper training. Proper crew operating procedures.		N/A
4.20	2. NPA [A.2.13]	Late arming of GPS approach	Proper training. Proper crew operating procedures.		N/A
4.21	2. NPA [A.2.13]	Intercept of GPS approach inside FAWP	Proper ATC training (limitation on ATC radar vectoring procedures. Increase pilot awareness of avionics limitations.		N/A
4.22	2. NPA [A.2.13]	Last minute change in navigation plan increasing workload	Proper pilot training to complete navigation planning prior to the approach.		ID3

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
4. Flightdeck issues (continued)					
4.23	4. BRNAV [A.4.28]	Partial loss of flight plan information (including the omission of information) that could result in useful information on navigation aids not being taken into account by the flight crew.	ATC will have dual radar surveillance cover for the ECAC airspace and significant deviations from track or potential erosion of safe separation with other aircraft should be detected and appropriate instructions given to the flight crew.	Identification of RAIM holes and DME/VOR outages on route would imply that the route should not be flown by a GPS-equipped aircraft with DME/VOR as its reversionary mode. EUROCONTROL's DEMETER program shows that the likelihood of there being insufficient (DME) beacon coverage is restricted to areas of low traffic density and overseas routes. There is a potential risk that, in such areas, with GPS and DME/VOR unavailable, aircraft will not be able to maintain RNP5.	N/A
4.24	4. BRNAV [A.4.28]	Partial loss, delay or degradation of pre-flight entered navigational data that could result in the deviation from the planned route, resulting in additional flight crew workload.	Flight crew should have either manual charts showing waypoints along the route, or automatic charting which would readily indicate to the flight crew the track that the aircraft was taking to the next waypoint. If the next point were significantly incorrect it would show up on the display.	Even though data is entered into the aircraft navigation system before departure there are no hazardous effects due to errors until the aircraft is airborne. Missing or incorrect waypoints for the route being flown will only become evident when the flight is in progress. The navigation system will indicate to the flight crew or direct the autopilot to fly in the direction of the next waypoint. If there is a significant deviation from the expected flight path the flight crew may well re-check their charts and discover the error. Otherwise, during this period, there is potential for the aircraft to deviate significantly from the intended flight path due to omissions in the pre-flight data without the flight crew noticing.	ID3

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
4. Flightdeck issues (continued)					
4.25	4. BRNAV [A.4.28]	Corruption or erroneous input of pre-flight navigation data could cause deviation from planned flight path and increased workload for the flight crew and ATC to resolve the situation.	The effective checking of the database and pre-flight checking by the flight crew will reduce the potential for this failure mode to occur. Any significant deviation from the planned RNAV route, which infringes RNAV route boundaries or reduces safe separation with other aircraft, should be identified by ATC and appropriate dialogue with the aircraft set up to resolve the issue. The work load of ATC will increase to resolve the issue.	The use of erroneous data will result in directions being given to the flight crew which will cause the aircraft to deviate from the actual planned route. Significant deviations from route will be observed by ATC who will intervene if separation standards are being eroded. The likelihood is that, with the next correct waypoint, the aircraft will be brought back to its intended route. The potential for a common mode fault in the database exists such that aircraft with the same database on different routes have the same waypoint entered. Investigation will be needed to establish the numbers of aircraft flying with the same database. The additional work load on ATC due to GPS database or position calculation needs to be investigated, as does the error (or tolerance) with respect to current navigation systems error. This will help to establish if there is any increase in risk when using GPS.	ID3
4.26	1. NPA [A.2.11]	Aircraft follows wrong course due to wrong approach selected by pilot from database		Not specific to GPS - may be less easy to detect as no further checks (such as pilot having to tune system to a specific navaid)	N/A
4.27	1. NPA [A.2.11]	Pilot does not follow guidance instructions	Pilot training in GPS-based navigationEnsure operating procedures are robust		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
4. Flightdeck issues (continued)					
4.28	1. NPA [A.2.11]	Pilot unaware of position errors (overconfidence in GPS data)	Pilot training. CDI must clearly indicate when guidance is not reliable due to loss of accurate position data	Concern expressed that with NPV approaches, if vertical guidance given as well as lateral, pilot may be misled into thinking it is a precision approach.	ID4
4.29	1. NPA [A.2.11]	Descent rate incorrect (pilot believes displayed range to next waypoint is range to runway TDZ)	Appropriate training in RNAV procedures should prevent this error. Consider introducing mandatory GNSS training as part of pilot licensing process.	Not GPS specific - related to use of RNAV procedures.	N/A
4.30	1. NPA [A.2.11]	Position errors not detected by pilot	Pilot training. Procedures should include specific pilot checks		ID4
4.31	1. NPA [A.2.11]	Pilot unaware that position is not sufficiently accurate for phase of flight (RNP limits not changed)	TSO equipment should alert pilot to change of limits at appropriate point		ID4
5. Airline Operations					
5.1	3. PRNAV [A.4.17]	Terrain clearance	ICAO Doc. 7030 [A.6.15] needs to be converted into suitable training material		N/A
5.2	3. PRNAV [A.4.17]	SOPs	Standard Operating Procedures (SOPs) need to be adjusted/tuned for RNAV procedures.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
5. Airline Operations (continued)					
5.3	2. NPA [A.2.13]	Confusion between GPS and DME readings	Procedural design: it is recommended not to publish the DME table, in case of a GPS procedure. Procedural design: prescribe strict SOPs with only GPS procedures in sight.		N/A
5.4	3. PRNAV [A.4.17]	Monitoring	Monitoring by operators/airlines needs to be ensured - section 10.4 of TGL 10 [A.3.4] describes incident reporting requirements. While this emphasises incidents arising from equipment issues, deviations arising from human factors/ procedural issues should be treated equally seriously as these could highlight weaknesses in the overall system.		N/A
5.5	3. PRNAV [A.4.17]	Flight planning	Airline/operator procedures for recording navigation equipment on Flight Plans need to be revised in accordance with the proposed amendment to new ICAO Doc. 7030 Serial No.: EUR/NAT-S 01/48-EUR RAC/16) [A.6.15].		N/A
5.6	3. PRNAV [A.4.17]	Training	Training of airline operations ground staff (and contractors) needs to include IFPS rules and the importance of ensuring the flight plan has the correct RNAV capability.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
6. Air Traffic Control issues					
6.1	3. PRNAV [A.4.17] 2. NPA [A.2.13] 1. NPA [A.2.11]	ATCO clears aircraft to inappropriate waypoint. ATC communication: cleared to waypoint not in the active flight plan. Aircraft follows wrong course due to incorrect clearance information from controller	Appropriate training for pilots and controllers is required. ATC training to promote awareness by ATC controller of consequences in aircrew workload in the cockpit. Pilot training to promote awareness of airport conditions (runway configurations and obstacles). Pilot should query if not expected approach.		N/A
6.2	3. PRNAV [A.4.17]	ATCO gives clearance incompatible with aircraft equipage.		This item poses an urgent open issue and requires harmonisation on ICAO level.	N/A
6.3	3. PRNAV [A.4.17]	ATCO forgets to control conventionally equipped aircraft when nearly all aircraft are RNAV equipped (mix of monitoring and controlling leads to errors of oversight).	See ATSPs/ States below	Software upgrades of the FDP-Systems plus appropriate training for controllers are required.	N/A
6.4	3. PRNAV [A.4.17]	With two aircraft on downwind at both sides of final, both aircraft simultaneously turn to final at the last waypoint.		Although this item is not specific to RNAV, the above-mentioned issues are currently under investigation and need an internationally agreed standard.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
6. Air Traffic Control issues (continued)					
6.5	3. PRNAV [A.4.17]	Responsibility for terrain clearance by a 'direct to' not clear to all ATCOs and pilots.	Terrain clearance responsibilities need clarification. ICAO Doc. 4444 [A.6.6] and states' national ATS manuals should be amended to clearly specify controllers' responsibilities for terrain clearance depending upon type of service being provided and type of surveillance display system used. The proposed revision to ICAO Doc. 7030, Serial No.: EUR/NAT-S 01/48-EUR RAC/16 [A.6.15] addresses this problem; this needs to be translated into appropriate ATS instructions and training material for controllers and flight crew. ATC training should cover terrain clearance situational awareness when giving clearances to waypoints not published as integral elements of a TA procedure: e.g. executing a Direct To clearance.	This item is open and requires harmonisation on ICAO level.	N/A
6.6	3. PRNAV [A.4.17]	Use of tactical waypoints	ATC training should cover awareness of aircraft RNAV system limitations and use of tactical waypoints.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
6. Air Traffic Control issues (continued)					
6.7	3. PRNAV [A.4.17] 4. BRNAV [A.4.28]	Navaid outagesIncrease in ATC workload as a result of the loss of an on-board ability to receive or analyse GPS satellite signals resulting in the loss of the aircraft's position data.	The ATC response to navaid outages should be included in RNAV awareness education given the different relationship between navaids and procedures in an RNAV environment.	If the aircraft deviates by more than RNP5 then either the flight crew will request assistance or, if the RNAV route boundary limits are exceeded, ATC will make contact with the flight crew. In either case the ATC workload increases to deal with the issue and during that time their monitoring of other aircraft under their surveillance is reduced. The number of aircraft that may be in this situation at any one time, and therefore will require the assistance of ATC, will be dependent on the reliability and quality of the onboard equipment and the ability of the flight crew to navigate using the reversionary navigation aids. In general it is considered that no more than one aircraft in a sector should be affected at any one time. In all the overall risk to aircraft is considered to be remote.	N/A
6.8	4. BRNAV [A.4.28]	Undetected corruption of RAIM will result in increased ATC workload as a result the deviation of aircraft from planned route.		There is no immediate effect on ATC as a result of false RAIM integrity. However, if the flight crew, in acting on that data, cause the aircraft to deviate from its planned flight path then ATC will have an increased work load to intervene and get the aircraft back on track. This situation will arise only where the flight crew have not detected the deviation themselves, or have not been able to maintain RNP when subsequently using the reversionary mode of navigation. This can occur where the deviation is gradual. In such cases the risk of infringing safe separation is limited due to the low rate of deviation.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
6. Air Traffic Control issues (continued)					
6.9	3. PRNAV [A.4.17]	Contingencies	ATC training should cover contingencies.		N/A
6.10	3. PRNAV [A.4.17]	Too long R/T to identify the correct transition.Conventional arrival and RNAV transition have similar identifications, which leads to confusion with the pilot (not sure which clearance is given by the controller), or with the controller (not sure which arrival / transition the aircraft will follow, even after pilot confirmation). Ambiguity over which vertical profile to follow for the pilots.		This item is not yet covered by the international standards and guideline documents. A harmonised operational concept is required. The R/T has to be adopted accordingly	N/A
6.11	3. PRNAV [A.4.17]	RT discipline	ATC training should cover the need to maintain RT discipline. Although not solely a P-RNAV issue, the greater use of alphanumeric identifiers in Tactical Waypoint naming raises the importance of using correct RT, still further.		N/A
6.12	3. PRNAV [A.4.17]	RTF phraseology	Consideration should be given to amending ICAO Doc. 7030 [A.6.15] with additional RTF phraseology to include turn direction when issuing "Direct To" clearances to aid pilots in detecting unexpected turns.		N/A
6.13	3. PRNAV [A.4.17]	The complex nature of switching between all RNAV procedures and all radar vectors by ATCO leads to confusion.	See Additional Documentation issues, below, regarding the Operational Concept	The complexity highlights the distinct need for a sound operational concept for the introduction of RNAV in the TMA with acknowledgement of the actual system capabilities.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
6. Air Traffic Control issues (continued)					
6.14	3. PRNAV [A.4.17]	Loss of separation when ATCO does not realise that navigation accuracy of RNAV equipped aircraft does not increase when approaching waypoints.		Appropriate training for controllers is required.	N/A
6.15	1. NPA [A.2.11]	Aircraft follows wrong course and controller aware but unable to intervene (due to comms failure)		Not new to GPS, but may be easier to do, so need to be sure procedures are adequate	N/A
6.16	1. NPA [A.2.11]	Aircraft follows wrong course and controller unaware (due to radar failure or no radar)	Consider making visual display such as EFIS mandatory.		N/A
6.17	3. PRNAV [A.4.17]	Display of flight plan information	State regulatory requirements for ATSPs display of flight plan information need updating to ensure aircraft RNAV capability is known to controllers.		N/A
7. Ground Systems					
7.1	3. PRNAV [A.4.17]	Coverage by navigational infrastructure (e.g. VOR/DME or DME/DME) is not sufficient to allow the RNAV system to continuously compute its position with the desired accuracy.		TGL 10 [A.3.4] partially calls up inappropriate standards and assumes inappropriate prerequisites for the other RNAV positioning sensors.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
7. Ground Systems (continued)					
7.2	3. PRNAV [A.4.17]	VOR/DME is not considered a sole P-RNAV sensor.		TGL 10 [A.3.4] and PANS OPS [A.6.7] have to be amended in order to:Highlight that VOR/DME is not a stand-alone means for P-RNAV.Clarify in which cases VOR/DME is considered as an acceptable means (may only be used in exceptional cases where no other P-RNAV means are available). Clarify the applicability of the procedure design criteria for TMA RNAV procedures. Highlight the potential to loose the operational benefits out of RNAV when the procedure has to be protected for the worst case VOR/DME instead of the worst case DME/DME, refer to 2.3.	N/A
7.3	3. PRNAV [A.4.17]	Use of offset DMEs by RNAV system.		As long as pilots have no influence on which DME station will be used by the RNAV equipment, as 2.3 refers, offset DMEs pose an unsolved safety concern. The requirement of TGL 10 [A.3.4] to exclude offset DMEs from the database is technically not feasible.	N/A
7.4	3. PRNAV [A.4.17]	Use of TACAN information and pre-1989 DMEs.		The discrepancies between the certification baselines and current avionics on one hand and the assumptions in Guide Doc [A.4.22], TGL 10 [A.3.4] and PANS OPS [A.6.7] on the other hand have to be solved. It still has to be determined, whether DMEs commissioned prior 1989 could be excluded from current navigation databases, and which impact this would have on the radio update capabilities.	N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
7. Ground Systems (continued)					
7.5	3. PRNAV [A.4.17]	OLDI	OLDI system requirements need updating to enable changed RNAV information to be updated - this has a knock on effect to ATSPs' Flight Data Processing (FDP) systems.		N/A
7.6	3. PRNAV [A.4.17]	Navaid decommissioning	When evaluating the possible removal of navaids, consideration should be given to the impact for cross checking RNAV solutions using raw navigation data on RNAV routes.		N/A
7.7	3. PRNAV [A.4.17]	FDP systems	The opportunity for an aircraft to be cleared to use an inappropriate RNAV route could be significantly reduced if FDP Systems assigned routes to aircraft, and displayed the information to the controller, automatically as a function of the aircraft navigation capability included in the FPL/RPL.		N/A
8. GNSS Systems					
8.1	4. BRNAV [A.4.28]	Loss, partial loss, degradation, detected corruption or delay of GPS to an aircraft may result in the aircraft deviating from planned flight path requiring the intervention of ATC.	Unexpected deviations of aircraft from their filed flight plan which are likely to exceed RNAV route boundary limits should be identified by ATC and appropriate contact with the flight crew established to query the deviation.		ID4

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
8. GNSS Systems (continued)					
8.2	4. BRNAV [A.4.28]	Undetected corruption of navigation position information presented to the flight crew by GPS could result in the aircraft deviating from its intended flight path to the point of infringement of RNP5 and potentially losing separation with aircraft on parallel RNAV routes, separation with the ground, flying into hazardous weather, or flying over danger or military areas.	Flight crews should regularly cross check their position by alternative means. Flight crews will be required to have appropriate charts, overlays and manual navigation capability to enable cross checking to be carried out. Training for navigation using offset DME/VOR should be given to flight crews who fly aircraft with GPS as their only input to B-RNAV.	As aircraft generally manoeuvre gently the flight crew may be unaware of deviations from track due to the autopilot using inaccurate GPS information.	ID4
8.3	4. BRNAV [A.4.28]	Undetected corruption of navigation position information presented to flight crews by GPS could result in aircraft deviating from their intended flight paths to the point of infringement of RNAV route boundary limits and potentially losing separation with other aircraft.	ATC becomes the first line of mitigation for the situation to be observed and action taken to correct it.	In busy sectors, where a number of aircraft are using GPS as their only input to B-RNAV, the undetected corruption of navigational data could affect one or many aircraft.	ID4
8.4	4. BRNAV [A.4.28]	Loss of on-board ability to receive or analyse GPS satellite signals, resulting in the loss of the aircraft's position data and an increase in flight crew work load.	It is assumed that the flight crew will be alerted to this situation and revert to alternative means of navigation. The equipment must therefore have a failure indication.		ID5
8.5	1. NPA [A.2.11]	Aircraft position data inaccurate or unavailable (pilot aware)	Confirm RAIM warning clearly visible in pilot's primary field of view (especially during final approach). Area should be tested for interference when procedure designed, and then monitored to ensure no new problems arise.	No protection against creeping errors if no airfield radar. Signal loss due to terrain blocking most likely just when high precision needed (e.g. in mountainous terrain).	ID4, ID5

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
8. GNSS Systems (continued)					
8.6	1. NPA [A.2.11]	Aircraft position inaccurate and pilot unaware.	Confirm RAIM warning clearly visible in pilot's primary field of view (especially important in phases 3 and 4).	No protection against small or creeping errors (RAIM may not detect these anyway).	ID4
8.7	1. NPA [A.2.11]	Aircraft position data incorrectly calculated (GPS software error).	Conduct review of software design & testing of equipment. CAA has standards for software and hardware development, based on level of risk associated with the application. Confirm appropriate standards are in use for this system.		ID4
8.8	1. NPA [A.2.11]	Aircraft position incorrect (potential 10 sec delay in RAIM algorithm indicating loss of position data integrity).	Confirm the clearance zone has at least a 10 sec radius from any point on approach +/- RNP tolerances, and that safe headings are safely reachable from anywhere within this zone.	This does not remove the hazard as the aircraft may have been drifting off course for longer than 10 sec.	ID4
8.9	1. NPA [A.2.11]	Aircraft position data incorrect (GPS continues to estimate position after losing signal).	Appropriate standards for receiver software design.	Confirm TSO [A.5.5] requires loss of position data integrity to be indicated within 10 seconds.	ID4, ID5
8.10	1. NPA [A.2.11]	Obvious loss of GPS position data.	Pilot should receive clear indication of loss of position data.	If caused by jamming or DoD switching off satellites, potential increase in controller work load could be hazardous if no radar, no alternative navaid and several aircraft on frequency.	ID5
8.11	1. NPA [A.2.11]	Multiple aircraft lose position data simultaneously (insufficient satellite coverage at time of arrival).	Consider giving controllers local RAIM prediction for advance warning of potential problems. Consider only allowing GPS approaches at ATC units (not to FIS units).	Airfields may find certain times of day when GPS approaches cannot be used.	ID5

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
8. GNSS Systems (continued)					
8.12	2. NPA [A.2.13]	Reduced availability of GPS/RAIM; pilot does not check availability before the flight; pilot does not take into account result of RAIM prediction tool due to uncertainties in flight planning; pilot obtains wrong GPS availability prediction from RAIM tool; GPS availability changes during the flight and the pilot is not informed.	Cross check with conventional navaids. Increase awareness of the availability of the GPS/RAIM prediction tool. Integration with onboard navigation systems like GPS/INS.		ID4
8.13	4. BRNAV [A.4.28]	Loss or inability to perform RAIM hole prediction may result in an increase in flight crew workload.		The loss of RAIM hole prediction capability has no immediate impact on the flight crew since the navigation solution accuracy in the context of RNP 5 is not necessarily affected by RAIM unavailability. However, it will deprive the flight crew of knowledge of expected RAIM alarms, and possible loss of position solution, along the route and hence the readiness of the flight crew to begin navigation by the reversionary navigation system.	ID4

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
8. GNSS Systems (continued)					
8.14	4. BRNAV [A.4.28]	Undetected corruption of the RAIM hole prediction function.		TSO-C129a [A.5.5] requires only that equipment be capable of predicting RAIM unavailability within ±15 minutes of the destination point arrival time. Advance prediction during flight planning is susceptible to flight time changes around the time of departure that could significantly affect the validity of the predictions. Undetected entry errors must also be considered which might result in non-identification of existing holes or vice-versa. RAIM hole re-prediction immediately before or during a flight is susceptible to entry error as for flight planning. The reduction of risk to tolerably safe flight as a result of implementing a RAIM hole prediction facility needs to be further considered, as there are reasons for and against its use. Using prediction can introduce further failure modes. Undetected errors made during data entry or faults in the prediction software may result in the flight crew being complacent about navigation using GPS if no RAIM holes were predicted.	ID4

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
8. GNSS Systems (continued)					
8.15	4. BRNAV [A.4.28]	Undetected corruption of RAIM will result in increased flight crew work load as a result of RAIM indicating that it has lost its integrity when it has not, or the potential for deviation from planned route as a result of providing incorrect but credible location fixes.	RAIM false alarms should be limited, with the 'acceptable' number to be identified in subsequent analysis. ATC should detect that an aircraft is drifting off route. Risk of loss of safe separation under gentle drift conditions before ATC intervenes is considered to be extremely remote.	The presentation of corrupt but credible location data as a result of RAIM failing to identify loss of integrity will result in the flight crew using that data for navigation. Continued credible corruption without identification of loss of integrity could result in the aircraft deviating from track without the knowledge of the flight crew. If the deviation is rapid the flight crew would be expected to detect it, due to the aircraft bank angle change, especially if they were expecting continued straight and level flight. They would be expected to query their position and heading and perform cross checks using the reversionary navigation aid. Gradual drift will not be so readily detected by the flight crew and the risk exists that RNP5 accuracy limits would be infringed	ID4
9. ATSPs/States					
9.1	3. PRNAV [A.4.17]	Terrain clearance responsibilities.	ICAO Doc. 7030 [A.6.15] needs to be converted into appropriate ATS instructions and suitable training material.		N/A
9.2	3. PRNAV [A.4.17]	Mixed mode operations.	Minimise the mix of P-RNAV and B-RNAV routes in TA. In reality, practical constraints should minimise this in any case.		N/A
9.3	3. PRNAV [A.4.17]	Display of flight plan information.	ATS providers need to meet the proposed operational/regulatory requirements for display of flight plan information as discussed at ANT 25/26.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
9. ATSPs/States (continued)					
9.4	3. PRNAV [A.4.17]	Representation of RNAV procedures at consoles.	A pictorial representation of RNAV procedures should be available at radar consoles.		N/A
9.5	3. PRNAV [A.4.17]	General Safety Management System issues.	Particular aspects of SMSs (not confined to, but considered important for, P-RNAV) that were raised during this project were: The requirement for an effective, no blame, incident reporting culture/systems. (ESARR 4 [A.4.12])The careful stepwise introduction of P-RNAV routes overseen by regulator.ATC competence checking.Appropriate sector staffing.		N/A
9.6	3. PRNAV [A.4.17]	Safety Case	ATSPs need to make a safety case for their P-RNAV applications that address site specific issues not covered by a generic safety assessment. Production of an adequate safety case for significant changes to the ATM system is a key part of an effective SMS.		N/A
9.7	3. PRNAV [A.4.17]	Sectorisation.	The ATC "sectorisation" of TA and RNAV route planning should take account of the performance characteristics of P-RNAV aircraft. An assessment involving all relevant disciplines should be conducted prior to implementation of P-RNAV routes and/or related airspace.		N/A

ID	App (Ref)	Subject / Item	Mitigation	Issues	Link to hazard
9. ATSPs/States (continued)					
9.8	3. PRNAV [A.4.17]	Performance monitoring and audit.	Enhanced regulatory oversight is needed in respect of the RNAV activities of the operators and ATSPs through performance monitoring and audit of safety management systems.		N/A
9.9	3. PRNAV [A.4.17]	Incident reporting.	Consideration should be given to amending TGL 10/JAR-OPS 1 [A.3.4] to encourage the reporting of occurrences caused by human factors and procedural issues. This would be consistent with ESARR 4 [A.4.12].		N/A

References for risk register:

[1] NPA [A.2.11] Hazard Analysis of GNSS based NPA, Cambridge Consultants (for CAA), C6109-R-001a, and 14th December 1999 on behalf of the CAA.

[2] NPA [A.2.13] Safety Implications of GPS Based NPA Landing, NLR, NLR CC-LL-99-310, 21st September 1999.

[3] PRNAV [A.4.17] Safety issues affecting P-RNAV in the terminal area - /DNV & DFS joining summary report, Issue 1.

[4] BRNAV [A.4.28] Preliminary Safety Assessment of the use of GPS for B-RNAV, Eurocontrol, May 1997.

Part 1, Annex D Accuracy and traffic density analysis

D.1 Introduction

D.1.1 This annex examines navigation accuracy and traffic density of helicopter operations in the North Sea. The traffic density calculations are based on traffic levels in the northern North Sea.

D.2 Navigation accuracy

D.2.1 B-RNAV specifies a navigation accuracy of 5 NM for 95% of the time. This would be insufficient to ensure lateral spacing on the HMRs, which are spaced about 4.2 NM apart when 80 NM from Aberdeen.

D.2.2 However, navigation accuracy when using GPS is in fact expected to significantly exceed this accuracy. RTCA DO-208 (MOPS for airborne GPS equipment) gives the following figures for 95% accuracy when flying with GPS.

Table 1 95% navigation accuracy when flying with GPS (RTCA DO-208)

	Manual flight	**Coupled flight**
Position fix error	0.124 NM	0.124 NM
CD centring	0.2 NM	0.0 NM
Flight technical error	1.0 NM	0.25 NM
Total	**1.03 NM**	**0.28 NM**

D.2.3 Note that:

- These figures assume GPS Selective Availability is operational; which it is not at present so the position fix error shown in pessimistic.
- These figures are for fixed-wing operations. It is assumed that helicopter operations are not significantly different.

D.2.4 Assuming a normal distribution of errors, Table 2 shows the probability of certain navigation errors. At 80 NM range from Aberdeen (the area where radar coverage is limited), the route spacing is 4.2 NM.

Table 2 Navigation error probabilities

Probability of total navigation error exceeding	**Manual flight**	**Coupled flight**
2.1 NM	6×10^{-5}	0 (to computer accuracy)
4.2 NM	0 (to computer accuracy)	0 (to computer accuracy)

D.2.5 Note that errors in the GPS position fix are unlikely to be opposite at the same time for two helicopters close to each other. They would probably rely on the same GPS satellites and therefore have similar errors in their position fix. Hence helicopters close to each other would probably show errors in similar directions.

D.2.6 It can be seen that the probability of one helicopter infringing the track of another is small.

D.3 Traffic density calculations

D.3.1 The track occupancy calculation is based on the traffic sample of helicopter traffic provided by NATS for the day 18th March 2004. The busiest track was found to be 060, which carried 9 flights between 0741 and 1508 (based on times at 80 NM).

D.3.2 The worst case occupancy assumption is that all aircraft fly at 3,000ft.

D.3.3 The worst case occupancy figure will be given by the busiest hour on the 060 track. Table 25 gives the outbound times for helicopters on the 060 track:

Table 3 Outbound times on track 060

1	0708
2	0838
3	0906
4	1051
5	1104
6	1119
7	1129
8	1137
9	1430

D.3.4 By inspection, the busiest hour for flights is between 1051 and 1151, when there are 5 outbound flights on the track.

D.3.5 For another helicopter joining that track (possibly as a result of an error), the probability of collision with a helicopter on that track will be dependent on the track occupancy figure and the "exposure time" - the time that the second helicopter spends on that track, assuming that both helicopters are at the same flight level.

D.3.6 Helicopters flying inbound should be separated from those flying outbound by 1,000ft (500ft for traffic in the southern North Sea). Same direction traffic will not usually be vertically separated. Inter-installation traffic in the northern North Sea may fly at the same flight levels as outbound traffic (3,000ft or 1,000ft), otherwise it will fly at 500ft or 1,500ft. Inter-installation traffic in the southern North Sea may fly at the same flight levels as outbound traffic (3,000ft or 2,000ft), or inbound traffic (2,500 or 1,500ft) otherwise it will fly at 500ft or 1,500ft.

D.3.7 The probability of collision can be evaluated for each of three different cases:

- Where the helicopter joins a same direction track;
- Where the helicopter joins an opposite direction track;
- Where the helicopter flies across tracks.

D.3.8 The first case considers a helicopter joining a same direction track (i.e. flying in the same direction as the other helicopters on that track).

D.3.9 The probability of collision will be determined by the time and place at which the helicopter joins the track, and its velocity relative to other helicopters on the track.

D.3.10 Assuming that the 5 flights in the busiest hour are distributed evenly on the 060 track, the time spacing of flights will be 12 minutes, or, assuming a speed of 2 NM per minute, 12 x 2 = 24 NM.

D.3.11 It is assumed that the helicopter deviation will be detected (either by ATC or the pilot) by the time the helicopter reaches the next reporting point. This gives a maximum distance flown on the wrong track of 30 NM (given a maximum report delay of 15 minutes).

D.3.12 It is assumed that the maximum speed difference will be 10% of the average speed (assumed to be 2 NM per minute). Therefore, the maximum catch up distance between two helicopters with the maximum speed difference in the maximum time taken to detect that one of the helicopters is flying on the wrong track will be 15 x 0.1 x 2 = 3 NM.

D.3.13 Given that the spacing of the flights is 24 NM, the probability of collision will therefore be 3/24 = 0.125. However, this event may be mitigated by visual acquisition of the helicopter in front and lateral/vertical separation due to flight technical error.

D.3.14 This calculation should be repeated for the busiest inbound track however. Outbound helicopters are monitored by ATC until around 80 NM out, so it is less likely that they will join the wrong track as compared to inbound aircraft, which are not seen by ATC until they reach radar coverage.

D.3.15 The busiest inbound track is 069, with the following traffic recorded for the 18th March 2004:

Table 4 Inbound times on track 069 (recorded at 80 NM)

1	0810
2	1009
3	1159
4	1340
5	1353
6	1411
7	1432

D.3.16 By inspection, the busiest hour for flights is between 1340 and 1440, when there are 4 inbounds for that track.

D.3.17 Assuming that the 4 flights in the busiest hour are distributed evenly on the 069 track, the time spacing of flights will be 15 minutes, or, assuming a speed of 2 miles per minute, 15 x 2 = 30 NM. Using the same assumptions as previously on speed differential, the probability of collision will therefore be 3/30 = 0.1.

D.3.18 In the case of a helicopter joining an opposite direction track, the probability of collision will be dependent on the length of time spent on the track. As the exposure time grows, the probability of collision will approach 1 for helicopters not vertically separated. However, helicopters travelling in opposite directions on HMRs should be vertically separated by 1000ft in the northern North Sea and by 500ft in the southern North Sea. The probability of collision therefore will be mostly dependent on the probability of human error that results in both helicopters being at the same altitude.

D.3.19 The hazard analysis [11] gives probabilities of various pilot errors. A value of around 10^{-3} is shown as typical for flight data entries, e.g. FMS waypoint insertion errors. But altitude mis-selections are much less likely on an HMR, since all pilots are trained to know the altitudes of in-bound and out-bound flights. A less conservative figure of 10^{-4} is assumed here.

D.3.20 In the case of a flight deviating across tracks, the worst-case situation is where a helicopter deviates at 90 degrees to the tracks at 80 NM out from Aberdeen. Assuming that the error will be detected after a maximum time of 15 minutes, the number of tracks crossed in that time will be 7 (assuming a track spacing of 4.2 miles at 80 miles out). Three of those tracks will have traffic at the same altitude.

D.3.21 The crossing time of tracks is assumed to be the time taken to clear the length of a helicopter on that track. The length of a helicopter is approximately 20m. Assuming a speed of 2 miles per minute = 62 meters per second, the crossing time will be approximately 0.3 of a second. During the busiest hour, the number of helicopters flying along track 060 is 5. Therefore, the probability of encountering a helicopter on the track in the 0.3 second crossing time is $5 \times 0.3/3600 = 4.6 \times 10^{-4}$.

D.3.22 Given that three tracks are crossed with helicopters at the same flight level before the deviation is detected, the probability of collision is given by $3 \times 4.6 \times 10^{-4} = 1.4 \times 10^{-3}$.

D.3.23 As an example of a flight crossing tracks (not deviating from its intended route, however), the following inter-installation flight was recorded on the 18th March schedule:

Table 5 Example inter-installation flight (18th March)

LIFTING TIME	CALLSIGN	FROM (HMR/range)	TO (HMR/range)	LEVEL
0819	BHL70A	TRITON (102/101)	UISGE GORM (114/191)	3A

D.3.24 The flight crosses a total of 5 HMRs, three outbound (102, 108, 114) and two inbound (105 and 111).

D.3.25 Table 28 presents a summary of collision risk for each of the three cases described above, assuming the busiest hour of the busiest track. The figures calculated above are modified to take into account the vertical overlap probability, i.e. the probability that two helicopters flying at the same indicated altitude would in fact be at the same altitude. For the North Atlantic, the figure given by NATSPG (NATSPG 2002) is 0.48. It is assumed that the same overlap probability can be applied to helicopters flying in the North Sea.

Table 6 Collision risk

Type of risk	Collision risk	Collision risk taking into account vertical overlap
Flying incorrectly on same direction outbound HMR	1.25×10^{-1}	6×10^{-2}
Flying incorrectly on same direction inbound HMR	1×10^{-1}	4.8×10^{-2}
Flying incorrectly on opposite direction HMR	1.0×10^{-3}	4.8×10^{-4}
Flying incorrectly across HMRs	1.4×10^{-3} (4.6×10^{-4} per track)	6.7×10^{-4} (2.2×10^{-4} per track)

D.3.26 It should be noted that for estimation of risk probabilities in the case of a helicopter joining the same direction track, the more conservative inbound figure is used.

D.3.27 In all cases, collision risks are rounded to the nearest order of magnitude when used in the hazard assessment.

Part 2 Airborne Radar Approach (ARA)

1 Introduction

1.1 General

1.1.1 This part of the report examines the hazards associated with the Airborne Radar Approach (ARA) procedure with the objective of identifying any weaknesses that a GPS-based procedure would need to address. The analysis therefore excludes the use of GPS in assisting an ARA. Part 3 of this report assesses the procedure where existing North Sea helicopter GPS equipment is used to assist the ARA.

1.1.2 The analysis in this section is structured as follows:

- Description of ARA procedure (Section 2).
- Hazard identification (Section 3).
- Conflict scenario analysis (Section 4).
- Conclusions and recommendations (Section 5).
- ARA equipment and maintenance procedures (Annex A).
- CHIRP events (Annex B).
- HOMP events (Annex C).
- MOR events (Annex D).
- Information from RDR-1400 Manufacturers (Annex E).
- Weather radar maintenance and test requirements (Annex F).
- RDR-1400 operations and maintenance (Annex G).
- Radio altimeter check procedures (Annex H).
- Computer simulation of ARA risks (Annex I).
- Results from NASA flight test program (Annex J).

1.2 Relationship to previous work

1.2.1 Simulation work had previously been undertaken to determine the safety of ARAs in the 'success case', i.e. when all equipment is functioning within tolerance. The simulation work was used to demonstrate the safety of a 0.75 NM Minimum Decision Range (MDR) with known equipment tolerances, and is described in Annex I. The analysis contained in this part of the report focuses on the 'failure case', i.e. when equipment or procedures fail during an ARA.

2 Description of ARA procedure

2.1 Introduction

2.1.1 The following details of the ARA procedure are taken from JAA IEM Appendix 1 to JAR-OPS 3.430 subparagraph (i). The minima for the procedure are contained in JAR-OPS 3.430 Appendix 1. Any differences between JAR-OPS and the procedures used by the operators have been noted as additions or alterations.

2.2 General and prior to commencing approach

2.2.1 Before commencing the approach, the identity of the destination radar return must be confirmed through one or more of the following means:

- By correlating the position of the radar return with the RNAV display. For helicopters with an overlay facility that displays the RNAV waypoints on the weather radar, cross-checking can be carried out to confirm that the platform waypoint is coincident with the weather radar return.
- Through identification of location in relation to neighbouring installations on the weather radar. The weather radar returns may be compared to a printed field chart.
- Checking that there are no other NDBs broadcasting, then having the destination's NDB switched on, checking its identification code and then flying the ARA procedure from the overhead.

2.2.2 The approach can consist of up to five separate segments. Only those segments that are required by local conditions applying at the time of the approach need be included in a procedure.

2.2.3 The final approach track should be identified first and orientated substantially into the wind. The installation wind is passed to the helicopter by the installation radio operator.

2.2.4 Vertical separation from obstacles is applied during the arrival, initial and intermediate segments, while horizontal separation is applied in the final and missed approach segments.

2.2.5 The approach is usually flown with the weather radar in map mode.

2.2.6 Note that JAR-OPS does not specify the maximum wind speed or relative wind direction for which the procedure is safe.

2.2.7 When operated by two flight crew members (where two crew members are required), one flight crew member is assigned a handling role, while the other is assigned the non-handling role. The allocation of roles may be based on experience or the approach orientation.

2.2.8 The handling flight crew member under IMC conditions will fly using instruments alone. The non-handling flight crew member takes responsibility for:

- Monitoring the weather radar.
- Monitoring instruments to check height/heading/speed.
- Monitoring the situation outside the cockpit.
- Giving heading instructions to the pilot.
- Commanding the pilot to initiate the offset at the OIP.
- Ensuring that the correct offset is achieved at 1 NM range from installation.
- Commanding the pilot to go around if required.

2.2.9 CHC Scotia additions:

- ARA procedures shall be acceptable to the Authority.
- ARAs are only permitted to installations or vessels underway when two pilots are operating the helicopter.
- A Commander shall not undertake an ARA unless the radar can provide course guidance to ensure obstacle clearance (in other words, the radar must be functioning correctly).
- Before commencing the final approach the Commander shall ensure that a clear path exists on the radar screen for the final and missed approach segments.
- If lateral clearance from any obstacle will be less than 1 NM, the Commander shall:
  - Approach to a nearby target structure and thereafter proceed visually to the destination structure; or
  - Make the approach from another direction leading to a circling manoeuvre.
- The Commander shall ensure that the cloud ceiling is sufficiently clear above the helideck to permit a safe landing.
- The Minimum Descent Height (MDH) shall not be less than 50 feet above the elevation of the deck, and no lower than 200 feet by day and 300 feet by night.
- The MDH for an approach leading to a circling manoeuvre shall be no lower than 300 feet by day and 500 feet by night.
- The approach is flown with the weather radar in weather mode.

2.2.10 Bristow additions:

- Prior to commencing the procedure, the following details must be obtained or confirmed:
  - Wind, visibility, cloud and barometric pressure at the offshore destination.
  - Availability status of the installation NDB.
  - Correct functioning of the aircraft's weather radar.
  - Final Approach Track orientated as far as possible into the prevailing wind.
  - Approach minima (MDH and Missed Approach Point (MAPt)).
  - Allocation of handling and non-handling pilot duties.
- Minimum Safe Altitude (MSA) at 1,500ft implies that there are no obstacles above 500ft within 10 NM of the offshore destination. If this is not the case, then the MSA should be increased accordingly in the appropriate sector.
- When more than one aircraft is using the procedure at the same location, then a separation standard of 1,000ft vertically or 15 NM horizontally is applied.

2.3 Arrival segment

2.3.1 The arrival segment commences at the last en-route navigation fix where the aircraft leaves the helicopter route.

2.3.2 It ends at the Initial Approach Fix (IAF) or, if no course reversal is required, at the Intermediate Fix (IF).

2.3.3 Standard en-route obstacle clearance criteria are applied to the arrival segment.

2.3.4 Before descent onto the approach, the radio altimeter is cross-checked against the barometric altimeter.

2.4 Initial segment

2.4.1 The initial segment is only required in the case of course reversal, race track or arc procedure.

2.4.2 It commences at the IAF and ends at the Intermediate Fix (IF).

2.4.3 Minimum obstacle clearance (MOC), the height above the tallest obstacle, is at 1,000ft

2.4.4 Bristow addition: For the reciprocal approach, the procedure commences from overhead the destination with an outbound leg of 4 NM along a track offset 20 degrees from the reciprocal of the final approach track, descending to 1,000ft.

2.5 Intermediate segment

2.5.1 The intermediate segment commences at the IF.

2.5.2 It ends at the Final Approach Fix (FAF) and should be no less than 2 NM in length.

2.5.3 Bristow alteration: The Bristow procedure does not include an intermediate segment (see Figure 3 and Figure 4).

2.5.4 The purpose of this segment is to align and prepare the helicopter for the final approach.

2.5.5 The destination should be identified on the weather radar, and the final approach and missed approach areas should be identified and verified to be clear of radar returns.

2.5.6 MOC is at 500ft.

2.5.7 Prior to descent, the radar altimeter and barometric altimeter are cross-checked.

2.6 Final segment

2.6.1 The final approach commences at the FAF (located at least 4 NM from the destination) and ends at the missed approach point (MAPt).

2.6.2 The final approach area takes the form of a corridor between the FAF and the radar return of the destination. The corridor is not less than 2 NM wide in order that the projected track of the helicopter does not pass closer than 1 NM to the obstacles lying outside the area.

2.6.3 Scotia addition: With the radar on a 10 NM scale, the intersection of the 2 mile range ring with the 30 degree azimuth line is at 1 NM laterally from track, allowing an easy visualisation of the 2 NM corridor.

2.6.4 On passing FAF, the helicopter descends below intermediate approach altitude on a descent gradient no more than 6.5%.

2.6.5 Scotia addition: The normal gradient is 5%, which equates to a 2.8 degree slope or 300 feet per NM. The maximum gradient is 6.5%.

2.6.6 Descent from 1,000ft msl to 200ft msl at 6.5% will take around 2 NM. In order to avoid levelling off at MDH and simultaneously changing heading at the Offset Initiation Point (OIP), the FAF should not be located at less than 4 NM from the destination.

2.6.7 The final approach is flown using the radio altimeter (not barometric) for vertical guidance. The Audio Voice Alerting Device (AVAD) will warn the aircrew if, for any reason, the altitude falls to 100ft. The crew can also set their own warnings on the AVAD.

2.6.8 Some operators use autopilot, but its use is varied and informal.

2.6.9 Bristow addition: All procedures should aim to establish a final approach track at 5 NM, prior to reaching the FAF at 4 NM. By FAF, the destination should be re-identified and the following verified:

- That the final approach area is clear.
- That the missed approach area is clear.

2.6.10 During final approach, the direct heading to the destination should be identified. This heading is maintained up to the OIP at 1.5 NM from the destination.

2.6.11 A heading change of 10 degrees is executed at the OIP, which means that the helicopter would be around 300-400m to one side of the destination structure at the closest point of approach.

2.6.12 Bristow addition: No turn back towards destination is allowed after OIP until in acceptable visual contact with the destination. At 1 NM the offset should be confirmed at 15 degrees. If it is less, the heading should be adjusted accordingly and flight should continue to the MAPt.

2.6.13 Ground speed should be no greater than 70kts.

2.6.14 Bristow alteration: Max speed should be 80kts ground speed by 2 NM.

2.6.15 The destination shall be in view in order that a safe landing may be carried out. On sighting the destination, or target of the approach, the visual landing manoeuvre can be commenced so as to take the aircraft to the destination helideck. The instrument approach procedure is terminated, and the aircraft is then manoeuvred as required to land.

2.7 Missed approach segment

2.7.1 If visual contact is not established by the Missed Approach Point (MAPt), defined to be at 0.75 NM Decision Range (taken as the radar range) from the platform, a missed approach is executed.

2.7.2 Bristow addition: The missed approach procedure should also be carried out if radar contact is lost or becomes unreliable when inbound and still in IMC.

2.7.3 The segment ends when the helicopter reaches the minimum en-route altitude.

2.7.4 The manoeuvre is a "turning missed approach" which should be between 30 and 45 degrees from the current heading.

2.7.5 Bristow alteration: The climbing turn should be a minimum of 45 degrees away from the heading towards the destination structure. No radar contact should be overflown until above MSA.

2.7.6 The missed approach area should be identified and verified as clear of obstacles on the radar screen during the intermediate approach segment.

2.7.7 The base of the missed approach area is a 2.5% gradient starting from MDH at the MAPt.

2.8 Procedure diagrams

2.8.1 The following figures show the ARA procedures described above. Three variants have been presented, the reciprocal approach (single arrow), the direct approach (double arrow) and the racetrack approach (triple arrow).

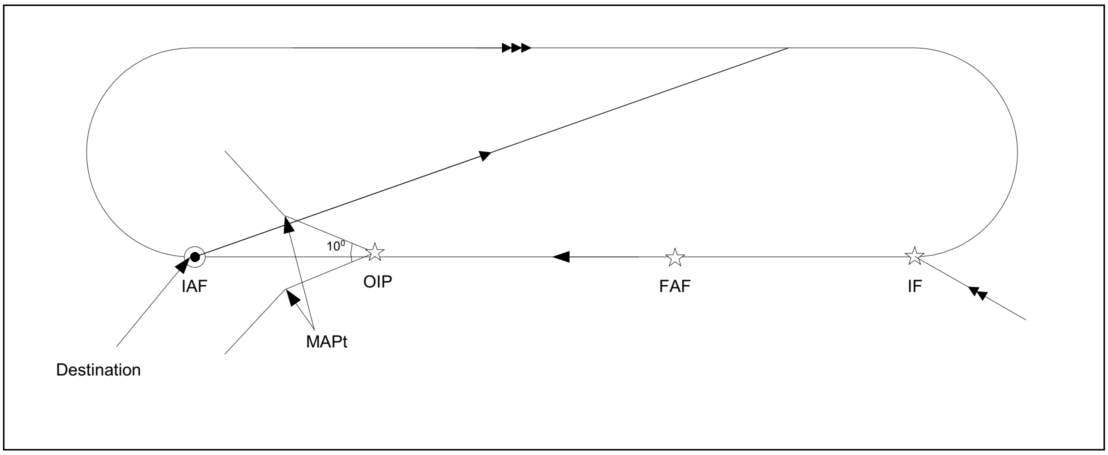

Figure 1 ARA approach procedures (Scotia, Bond and JAR-OPS)

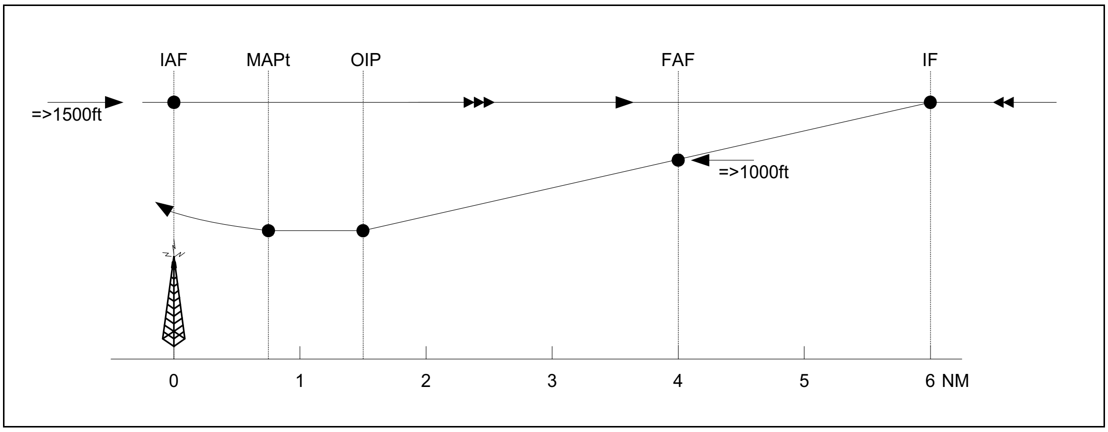

Figure 2 ARA approach procedures (vertical profile) (Scotia, Bond and JAR-OPS)

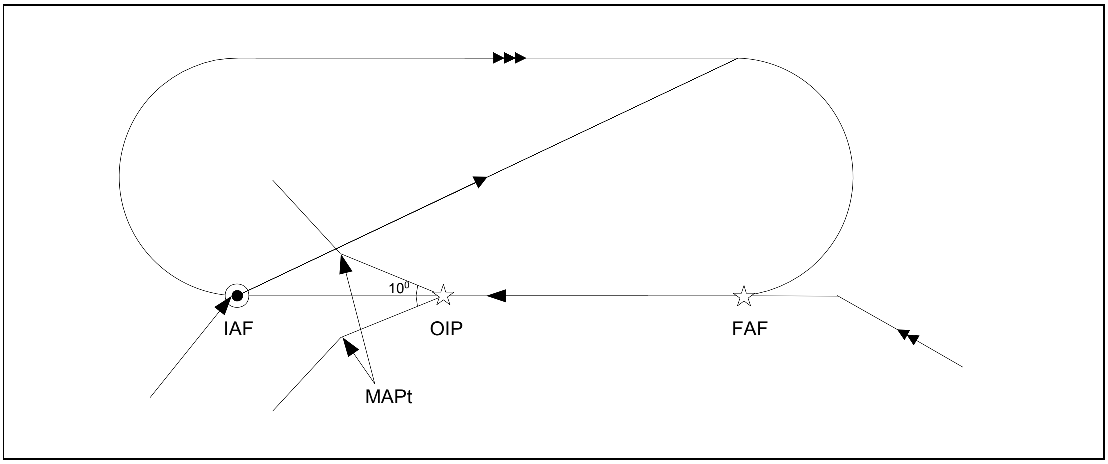

Figure 3 ARA approach procedures (Bristow)

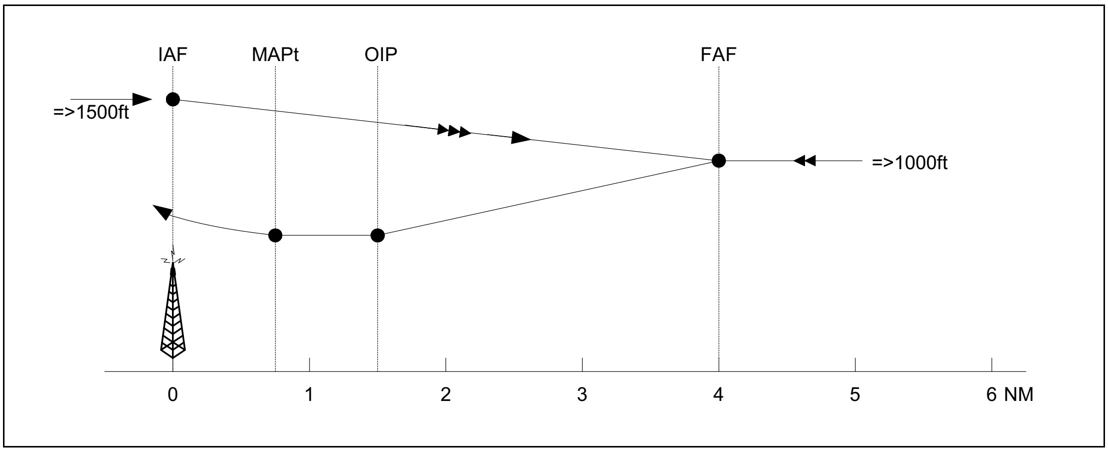

Figure 4 ARA approach procedures (vertical profile) (Bristow)

3 Hazard identification

3.1 Introduction

3.1.1 This section identifies and qualitatively discusses the hazards that are associated with ARAs conducted in accordance with the procedures described in the previous section.

3.1.2 The hazards were identified through a HAZID session within Helios and were then compared with hazards identified in other phases of the project and reviewed with the CAA. The hazards have been merged into a consolidated list which is summarised in Table 1.

Table 1 Consolidated list of hazards

ID	Hazard
1	Weather radar displays incorrect information.
2	ADF displays incorrect information.
3	Altimeter(s) displays incorrect information.
4	Compass displays incorrect information.
5	Wrong wind information from rig.
6	Miscommunication between/with flight crew.
7	Flight crew error - misinterpretation of information.
8	Flight crew error - incorrect selection/operation of equipment.
9	Flight crew error - distraction/inattention/disorientation.

3.1.3 Note that the hazard of total failure of weather radar, ADF or altimeters are not included since it is assumed that these would be detected by the flight crew who would, if necessary, terminate the ARA. General and prior to commencing approach

3.2 ID1: Weather radar displays incorrect information

3.2.1 This hazard occurs if the information displayed to the flight crew by the weather radar is incorrect. It results from a partial, unannunciated failure of the weather radar and causes incomplete, inaccurate or partial data to be displayed.

3.3 ID2: ADF displays incorrect information

3.3.1 This hazard occurs if the ADF presents incorrect information to the flight crew. It results from a partial, unannunciated failure of the ADF. It could also be caused by a NDB on a nearby installation sharing the same frequency and being switched on as well as or instead of the one at the destination installation. To approach an incorrect NDB, the flight crew would need to fail to correctly check the NDB ident.

3.3.2 Pilots report that NDBs are recognised as an unreliable navaid and therefore always used with some caution.

3.4 ID3: Altimeter displays incorrect information

3.4.1 This hazard occurs if the altimetry information presented to the flight crew is incorrect. This hazard occurs due to partial, unannunciated failure of the radio altimeter(s) in the final approach segment.

3.4.2 As described in the procedure description, the final approach is flown using only the radio altimeter. There is a cross-check between radio and barometric altimeters before the descent at the FAF and a failure of the barometric altimeter after this point would not affect the approach. On aircraft types (e.g. EC225) the baro and radio altimeter strip gauges are adjacent which aids the cross-check.

3.4.3 Modern aircraft have three barometric altimeters which are automatically monitored and cross-checked. Any discrepancy is highlighted to the crew.

3.4.4 Radio altimeters also have automatic height warnings at fixed and pilot selectable heights. Some aircraft also have dual radio altimeters, each equipped with these height warnings.

3.4.5 The most critical failure of a radio altimeter would be a "stuck" height reading on an aircraft with only a single radio altimeter while the aircraft is flying at low altitude in low visibility.

3.5 ID4: Compass displays incorrect information

3.5.1 This hazard occurs when the compass displays incorrect information to the flight crew. It results from a partial, unannunciated failure of the compass.

3.5.2 There are usually three compass systems on the helicopter. In modern aircraft a heading discrepancy between the two main systems is annunciated to the crew.

3.5.3 During the ARA final approach, indicated heading is largely irrelevant as the flight path is adjusted so that the helicopter is flying towards the destination radar return. Only relative changes in heading are important in this segment.

3.6 ID5: Wrong wind from installation

3.6.1 In this hazard the flight crew are provided with incorrect wind information prior to commencing the approach to the installation. The wind information is used by the flight crew to plan the heading for the final approach. So the operational consequence of this hazard is usually that the approach has a significant cross-wind and the crew is not aware of it.

3.6.2 Some approaches are intentionally executed with a significant cross-wind due to obstacle restrictions. So a cross-wind approach is not necessarily a hazard in itself, but large drift angles can lead to confusion.

3.6.3 A significantly out-of-wind approach can also be detected by the aircrew by the need to continually make corrections to the heading. This would provide the crew with an indication that the reported wind was not correct.

3.6.4 An unexpected wind is most significant in the final visual landing phase where the helicopter is manoeuvring close to the rig.

3.6.5 An example of this hazard is MOR 197605128 on 12 November 1976, documented in D.2.2 (incorrect wind direction passed from installation). However, note that some equipment and standards have changed since this MOR.

3.6.6 The hazard could result from:

- Incorrect readings taken on the installation due to human error or equipment failure.
- Out-of-date information provided to the flight crew.
- Changes in wind speed and/or direction.

3.6.7 Note that MOR 198102967 on 18 September 1981, documented in D.2.5 (incorrect QFE) describes a different but related hazard - where the flight crew are provided with incorrect local pressure setting. This hazard is not investigated further here as the final approach is flown using the radio altimeter height only.

3.7 ID6: Miscommunication between flight crew or between installation and flight crew

3.7.1 This hazard occurs if there is a mistake in the communication between the flight crew themselves, or between the flight crew and the installation. In this hazard, even if correct information is passed from the installation, the flight crew may mis-read or mis-transpose the information.

3.8 ID7: Flight crew error - misinterpretation of weather radar information

3.8.1 In this hazard the flight crew misidentify or miss-locate the destination installation, or fail to detect or miss-locate an obstacle, as a result of the weather radar display becoming confusing due to precipitation and/or sea clutter.

3.8.2 Other instruments such as altimeters, ADF and compass can also be miss-read, but these are much simpler than the weather radar so it has been assumed that the probability of miss-reading them is significantly less and the hazard is dominated by the probability of misinterpreting the weather radar display.

3.9 ID8: Flight crew error - incorrect selection/operation of equipment

3.9.1 In this hazard the flight crew make an error in the operation of equipment, for example:

- Incorrect adjustment of the weather radar (discussed below).
- Manual tuning errors of ADF, which could potentially cause an approach to an incorrect installation. This risk is minimised by the requirement to listen to and verify the NDB ident. Multiple NDBs transmitting simultaneously could also confuse the flight crew, although this is mitigated by the requirement to check the channel is clear before requesting that the NDB is turned on.
- Incorrect adjustment of pressure setting on the baro altimeter. This hazard is less relevant since the final approach is flown using the radio altimeter height.

3.9.2 The weather radar must be adjusted to provide the optimum picture for the approach. This adjustment includes gain, tilt and mode (map or weather) and will vary according to the sea state. Incorrect setting - especially of gain or tilt - could make obstacles or the destination less visible on the weather radar.

3.9.3 Although the radar is usually set to map mode, at least one operator flies it in weather mode. The differences between the modes appear to be equipment specific. For the RDR-1400, the differences are in display colours and sensitivity (the map mode has adjustable sensitivity).

3.9.4 This is a difficult hazard to assess since there is no "correct" setting - only more and less clear displays.

3.10 ID9: Flight crew error - distraction/inattention/disorientation

3.10.1 In this hazard the flight crew makes an error through distraction, inattention or disorientation.

3.10.2 Possibly the most significant example of this hazard is inadvertent drift down during the final approach potentially resulting in contact with the sea. However, in modern aircraft, this phase is conducted using the 'upper modes' of the autopilot providing altitude and speed hold.

3.10.3 Autopilot control is available in more than half the North Sea fleet, and the modern EC225 helicopter levels off automatically at 100ft. The EC225 procedures also require the use of autoflight systems in bad weather.

3.10.4 Older aircraft without these autopilot modes (e.g. S76) are more susceptible to this hazard.

3.10.5 It should be noted that the 'Alt Hold' autopilot mode is based on the barometric altimeter with slow updates. (Radio altimeter hold is available but cannot be engaged in IMC).

3.10.6 This hazard could also result in, e.g., the helicopter approaching the wrong rig or coming into conflict with an obstacle.

4 Conflict scenario analysis

4.1 Introduction

4.1.1 Conflict scenarios have been used to analyse the operational impact of the identified hazards . A conflict scenario represents the operational consequence of one or more hazards.

4.1.2 The following conflict scenarios have been identified:

- The helicopter approaches the wrong installation (CS1).
- The helicopter comes into conflict with the sea (CS2).
- The helicopter comes into conflict with an obstacle (CS3).
- The helicopter comes into conflict with the destination installation (CS4).

4.1.3 Table 2 shows the links between each of the conflict scenarios and the hazards.

Table 2 Relationship between hazards and conflict scenarios

Ref.	Description	CS1	CS2	CS3	CS4
ID1	Weather radar displays incorrect information	✓		✓	✓
ID2	ADF displays incorrect information	✓			
ID3	Altimeter displays incorrect information		✓		
ID4	Compass displays incorrect information	✓			
ID5	Wrong wind information from installation				✓
ID6	Miscommunication between flight crew or between flight crew and installation	✓			
ID7	Flight crew error - misinterpretation of information.	✓		✓	
ID8	Flight crew error - incorrect selection/operation of equipment	✓	✓	✓	✓
ID9	Flight crew error - distraction/inattention/ disorientation	✓	✓	✓	✓

4.2 Derivation of probabilities

4.2.1 Probabilities for equipment failure rates, human error rates and circumstantial probabilities in all the conflict scenarios are derived in this section.

4.2.2 For equipment failure a 'standard' failure rate of 10^{-5} per flight hour is used for barometric/radio altimeters, the weather radar, etc. This failure rate is typical of equipment that is flight essential (but not flight critical). This is used as the failure rate for events such as:

- Unannunciated failure of the radio altimeter.
- The weather radar displays installation in incorrect location.
- Obstacle is missing from the weather radar display.

4.2.2.1 While the weather radar does not have the same equipment certification as the altimeters, it does not (according to MOR data) have a noticeably higher equipment failure rate. Information received from Telephonics (see Annex E) has indicated that the RDR-1400 weather radar has been designed to a probability of providing misleading or erroneous information to the flight crew of 2.18×10^{-6} which is lower than the rate of 10^{-5} assumed.

4.2.3 In this section, the importance of expert judgement should be noted. No quantitative data are available for some factors. The uncertainty in the probabilities calculated should be borne in mind when considering the tolerability of different events. Where considered necessary, a sensitivity analysis is presented to test the significance of the assumptions made.

4.2.4 For the probability of human errors, the analysis assumes that flight crew errors occur with fixed probabilities. These have been derived by comparison with [11], as shown in Table 3:

Table 3 Generic human error rates

Assumed error rate	**Definition in [10] of action with this assumed error rate**
10^{-3}	Errors of omission such as operating wrong button or reading wrong display. More complex task, less time available, some cues necessary.
10^{-2}	Errors of omission where dependence is placed on situation cues and memory. Complex, unfamiliar task with little feedback and some distractions.
10^{-1}	Highly complex task, considerable stress, little time to perform it.

4.2.5 From this table, the following error rates for ARAs are derived.

Table 4 ARA human error rates

Frequency	**Error**
10^{-1}	**Single crew, short reaction time, information may be unclear** Examples in this report: • Fail to see and avoid sea in IMC (if unknowingly too low) • Fail to see and avoid destination in IMC (if unknowingly too close) • Fail to see and avoid obstacle in IMC (if unknowingly too close)
10^{-2}	**Single crew, standard cross-check or routine operation** Examples in this report: • Fail to correctly read destination name • Fail to see and avoid another helicopter in the visual phase of flight
10^{-3}	**Two crew, standard cross-check or routine operation** Examples in this report • Fail to monitor relationship between radio and barometric altimeters and rate of descent • Crew incorrectly locate destination on display • Helicopter descends below MDH due to crew error
10^{-5}	**Two crew, standard checks with warnings and/or the error would have to be sustained over several minutes** Examples in this report: • Monitor height visual warning and AVAD /EGPWS audio warnings • Flight crew fail to detect obstacle on weather radar
NOTE: Hazards are per flight hour	

4.2.6 Circumstantial probabilities of occurrence must also be calculated for:

- Approaching the wrong rig;
- An obstacle present in the final/missed approach path;
- Some part of the installation in the helicopter path.

4.2.7 MOR data illustrate the occurrence of approaching or landing on the wrong installation. Analysis of MOR data (over 30 years) shows 28 incidents where an aircraft approached or landed on the wrong installation. The MOR statistics give a reported rate of 1 in 50,000 incorrect approaches based on approximately 1 incorrect approach per year in which there are 50,000 approaches. Since under-reporting is known to occur in MORs, a factor of 10 has been added and a frequency of 1 in 5,000 (2×10^{-4}) is assumed in this analysis.

4.2.8 There is no data available on the probability of an obstacle in the final/missed approach path. To be a hazard, obstacles must be 200ft or greater above sea level. Most such obstacles are known to the crew by other means as they are offshore installations or semi-submersible installations and are shown on maps. Only installations under tow are likely to fall into this category. A probability of an obstacle in the path of 10^{-3} is assumed and discussed in the sensitivity analysis.

4.2.9 There is also no data available on the probability that some part of the installation is in the helicopter path. A probability of this event of 10^{-2} is assumed and discussed in the sensitivity analysis.

4.3 Conflict Scenario 1: The helicopter approaches the wrong installation

4.3.1 Description

4.3.1.1 In this scenario the helicopter approaches an installation it was not intending to land on. Note that approaching the wrong installation is not a hazard in itself - the risk lies in the subsequent visual landing at the wrong rig.

4.3.1.2 The conflict may be caused by flight crew error and may be the result of, for example, misreading the chart or miscommunication between the crew.

4.3.1.3 Alternatively, the error may be precipitated by incorrect or misleading information presented to the flight crew. Errors in wind information from the installation or changes in wind speed and/or direction may result in flight path errors and/or large drift angles which might lead to miss-identification of the destination. Incorrect information (e.g. due to unannunciated equipment failure) or confusing information (e.g. due to precipitation and/or sea clutter) on the weather radar display, compass errors or ADF errors may also cause the flight crew to miss-identify the destination.

4.3.1.4 Six hazards have been identified that could cause this conflict scenario, namely:

- ID1: Weather radar displays incorrect information. An incorrect positioning of the installation on the radar could confuse the flight crew into approaching the wrong installation where there are a number of installations in the field.
- ID2: ADF displays incorrect information. Incorrect ADF bearing or misreading of NDB ident could cause the helicopter to approach a different installation from the intended one.
- ID4: Compass displays incorrect information. Incorrect compass information could disorientate the crew and cause them to approach an incorrect installation. However, this failure would have to be combined with an incorrect interpretation of the weather radar or an incorrect display of installation positions on it.

- ID6: Miscommunication between flight crew or between installation and flight crew. Confusion between the flight crew members could cause them to approach the wrong installation.
- ID7: Flight crew error through misinterpretation of information. Miss-reading of the weather radar, especially in the presence of sea clutter and/or precipitation and/or a multi-installation field, could cause the crew to miss-identify the destination installation.
- ID8: Incorrect equipment setting. For example, incorrect weather radar range setting could cause the crew to confuse the desired installation with another one.

4.3.2 **Severity**

4.3.2.1 This conflict scenario may have little or no impact on safety if there are no other aircraft flying in the vicinity and the platform is in a safe condition to land on. This section focuses on those situations where a helicopter approaching the wrong installation could be critical. The possible consequences of CS1 are:

- The helicopter comes into conflict with another helicopter in the vicinity (CS1a), e.g. approaching the same or an adjacent installation. Note that the introduction of ACAS would alleviate this risk.
- The flight crew attempt to land on an installation that is not expecting a helicopter and is unsafe (CS1b), e.g. crane operating, obstacles and/or personnel on deck, hazardous operations in progress, hydrocarbon leak.

4.3.2.2 The chain of events that could result in the above consequences is presented in Table 5.

Table 5 Chain of events causing Conflict Scenario 1

Event	Hazardous chain of events	Severity
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	Helicopter approaches the wrong installation AND Another helicopter in the vicinity of installation AND Flight crew fail to see and avoid other helicopter	CATASTROPHIC
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	Helicopter approaches the wrong installation AND Flight crew fail to correctly identify installation AND Installation unsafe and flight crew not aware	CATASTROPHIC

4.3.2.3 Note that the detail of why the helicopter approaches the wrong installation has been omitted due to its complexity and the paucity of data on the probabilities of the individual hazards. Instead, the compound hazard (helicopter approaches the wrong installation) derived in paragraph 4.2.7 has been used to cover all the various combinations of the individual hazards.

4.3.3 Probability

4.3.3.1 Table 6 shows a summary of the probabilities associated with each of the events.

Table 6 Probability analysis for Conflict Scenario 1

Event	Hazardous chain of events	Severity
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	Helicopter approaches the wrong installation during ARA AND Another helicopter in the vicinity of installation AND Flight crew fail to see and avoid other helicopter	2×10^{-4} (note 1) 1×10^{-2} (note 2) 1×10^{-4} (note 3) **Total: 2×10^{-10}**
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	Helicopter approaches the wrong installation during ARA AND Flight crew fail to correctly identify installation AND Installation unsafe and flight crew not aware	2×10^{-4} (note 1) 1×10^{-2} (note 4) 1×10^{-2} (note 5) **Total: 2×10^{-8}**
Note 1: Assumed - see 4.2.7 Note 2: Assumed - see Part 3, Table 4. Note 3: Assumed - see 4.2.5, noting that the crews of both helicopters would need to fail to see and avoid. Note 4: Assumed - see 4.2.5 Note 5: Assumed - see Part 3, Table 4.		

4.3.4 Risk tolerability

4.3.4.1 Table 7 shows a summary of conflict scenario 1, based on the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 7 Summary of Conflict Scenario 1

Conflict Scenario 1: The helicopter approaches the wrong installation			
	Severity	**Probability**	**Result**
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	CATASTROPHIC	EXTREMELY REMOTE	UNACCEPTABLE

4.3.5 Sensitivity analysis and mitigations

4.3.5.1 To achieve a 'TOLERABLE' status for CS1b, the combined probabilities would have to fall by a factor of at least 20.

4.3.5.2 There are two initiatives that could mitigate against CS1, if and when they become available:

- For those helicopters equipped, ACAS would mitigate against conflict with another helicopter.
- The planned North Sea multilateration surveillance system would allow ATC to detect incorrect approaches or potential conflicts with other traffic. However, it is not known what ATC service will be offered with the system.

4.4 Conflict Scenario 2: The helicopter comes into conflict with the sea

4.4.1 Description

4.4.1.1 In this scenario the helicopter approaches the correct destination installation but, during approach, comes into conflict with the sea. The conflict may be caused through flight crew error or equipment failure.

4.4.1.2 The two hazards identified that could cause this conflict scenario are:

- ID3: Altimeter displays incorrect information. The final approach is flown with the radio altimeter (not baro) so this hazard specifically relates to radio altimeter malfunction. As described earlier, a cross-check is conducted between radar and barometric altimeters before starting the final approach.
- ID8: Flight crew error through incorrect selection/operation of equipment. In this case, incorrect reading of the altimeter could contribute to a descent below MDH.
- ID9: Flight crew error - distraction/inattention/disorientation, e.g. inadvertently descending below the MDH.

4.4.1.3 Table 8 shows the MORs related to descent below MDH:

Table 8 MOR events related to descent below MDH

Type	Number of occurrences	First report	Latest report
Descended below decision height	1	June 2003	
Malfunction of altimeter	5	August 1985	March 2001

4.4.1.4 The first MOR in the above table was an intentional descent below MDH and at least one of the others was caused when the aircraft crossed the deck edge which wouldn't occur during flight. None of unintentional descents below MDH were during an ARA. So the MOR data is not used for estimating the frequency of descents below MDH.

4.4.1.5 In addition to the MORs, there is one relevant HOMP incident and two CHIRP reports recorded.

4.4.1.6 The conflict scenario can occur in two ways: due to crew error or due to altimeter failure. For the latter case, the most hazardous failure is that the altimeter 'sticks' so that it does not show reducing altitude as the aircraft descends. Such an event would have to occur in the period after the cross-check with the baro-altimeter and there are no reported instances of it in the MORs.

4.4.1.7 A 'stuck' altimeter would be apparent by comparing the vertical speed and the stuck altimeter, so it should be detected by the flight crew.

4.4.1.8 Note that if the crew detect a radio altimeter failure or the low altitude warning sounds in the last mile, then a go-around is required.

4.4.1.9 Note that some modern aircraft are fitted with an automatic level-off function. This would prevent CS2a when and where it is available.

4.4.2 Severity

4.4.2.1 The chain of events that results in this conflict scenario is presented in Table 9:

Table 9 Chain of events causing Conflict Scenario 2

Event	**Hazardous chain of events**	**Severity**
2a. The helicopter comes into conflict with the sea due to crew error	Helicopter descends below MDH due to crew error AND Flight crew do not respond to AVAD/EGPWS warnings or '100ft' warning AND Flight crew fail to visually acquire the sea and react in time	CATASTROPHIC
2b. The helicopter comes into conflict with the sea due to altimeter failure	Unanunciated failure of the radio altimeter causes over-reading resulting in descent below MDH AND Flight crew fail to notice the discrepancy between the radio altimeter, baro altimeter and rate of descent AND Flight crew fail to visually acquire the sea and react in time.	CATASTROPHIC

4.4.3 Probability

4.4.3.1 Table 10 shows a summary of the probabilities associated with each of the events.

Table 10 Probability analysis for Conflict Scenario 2

Event	**Hazardous chain of events**	**Probability**
2a. The helicopter comes into conflict with the sea due to crew error	Helicopter descends below MDH due to crew error AND Flight crew do not respond to AVAD /EGPWS warnings or '100 feet' warning AND Flight crew fail to visually acquire the sea and react in time	1×10^{-5} (note 1) 1×10^{-5} (note 1) 1×10^{-1} (note 1) **Total 1×10^{-11}**
2b. The helicopter comes into conflict with the sea due to altimeter failure	Unanunciated failure of the radio altimeter causes over-reading resulting in descent below MDH AND Flight crew fail to notice the discrepancy between the radio altimeter, baro altimeter and rate of descent AND Flight crew fail to visually acquire the sea and react in time.	1×10^{-5} (note 2) 1×10^{-3} (note 1) 1×10^{-1} (note 1) **Total: 1×10^{-9}**
Note 1: Assumed - see 4.2.5. Note 2: Assumed - see 4.2.2.		

4.4.4 Risk tolerability

4.4.4.1 Table 11 shows a summary of conflict scenario 2, based on the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 11 Summary of Conflict Scenario 2

Conflict Scenario 2: The helicopter comes into conflict with sea			
	Severity	**Probability**	**Result**
2a. The helicopter comes into conflict with the sea due to crew error	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE	NEGLIGIBLE
2b. The helicopter comes into conflict with the sea due to altimeter failure	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE

4.4.5 Sensitivity analysis and mitigations

4.4.5.1 To achieve a 'NEGLIGIBLE' status for CS2b, the combined probabilities would have to fall by a factor of at least 100. This would be difficult to achieve given current equipment, but may be possible with future GNSS systems that are currently being investigated.

4.4.5.2 CS2b would be mitigated by installing a second radio altimeter, and it is recommended that this is further investigated.

4.5 Conflict scenario 3: The helicopter comes into conflict with an obstacle

4.5.1 Description

4.5.1.1 In this scenario the helicopter approaches the correct destination installation but comes into conflict with an obstacle during the approach or overshoot. Four hazards have been identified that could cause this conflict scenario:

- ID1: Weather radar displays incorrect information. This could mean that the final approach segment appeared clear of obstacles when it was not.
- ID7: Flight crew error through misinterpretation of information. For example, the crew may fail to detect obstacles in the final approach even though they are shown on the weather radar, e.g. due to sea clutter and/or precipitation.
- ID8: Incorrect equipment setting/operation, e.g. wrong range or tilt setting on weather radar, might lead to non-detection of obstacles.
- ID9: Flight crew error - distraction/inattention/disorientation. The crew may fail to detect obstacles by being distracted from the weather radar.

4.5.1.2 Since the flight crew must check that the final approach and go-around paths are clear of obstacles before starting the final approach, this scenario can only occur if that check fails to show one or more obstacles or the weather radar continuously incorrectly 'paints' them outside of the approach and/or go-around paths.

4.5.1.3 Precipitation or high sea states could cause the weather radar display to become cluttered which could make obstacles more difficult to see. Use of the sensitivity control could reduce the clutter, but some aircraft do not allow sensitivity adjustment in map mode. If the display is difficult to read (because of clutter or for any other reason), the crew should discontinue the approach. Information from the RDR-1400 manufacturer (Annex E) recognises the need for crew experience in detecting false targets and this is an area where training is important.

4.5.1.4 Finally, in Annex G a number of weather radar controls are identified that could typically be miss-set:

- The weather/map display mode. As noted in the description of ID8 (see 3.9.3), the use of weather radar mode is inconsistent between operators, and the hazards of selecting the wrong mode are inconsistent between equipment. Generally the pilot will use the mode which results in the best picture in the prevailing conditions.
- The range setting. An incorrect range setting on the weather radar can increase the minimum detection range, thus preventing display of nearby obstacles.
- The tilt control. With extreme tilt, it may be possible lose obstacles from the display, e.g. due to over-scanning.

4.5.2 Severity

4.5.2.1 The conflict scenario can arise in two ways:

- The helicopter comes into conflict with an obstacle in the vicinity of the destination installation due to flight crew error, e.g. the flight crew fail to notice the obstacle on the display due to clutter (ID7), or due to distraction or inattention (ID9).
- The helicopter comes into conflict with an obstacle in the vicinity of the destination installation due to the absence of the obstacle on the weather radar display, e.g. due to unannunciated failure of the weather radar (ID1), or miss-setting of the weather radar controls (ID8).

4.5.2.2 The chain of events that can result in either of these two consequences is presented in Table 12.

Table 12 Chain of events causing Conflict Scenario 3

Event	Chain of events required	Severity
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	Obstacle present without vertical separation AND Flight crew fail to detect obstacle on weather radar AND Flight crew fail to visually acquire obstacle and react in time.	CATASTROPHIC
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	Obstacle present without vertical separation AND The obstacle is missing from the weather radar display AND Flight crew fail to see obstacle and react in time.	CATASTROPHIC

4.5.3 Probability

4.5.3.1 Table 13 shows a summary of the probabilities associated with each of the events.

Table 13 Probability analysis for Conflict Scenario 3

Event	Chain of events required	Probability
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	Obstacle present without vertical separation AND Flight crew fail to detect obstacle on weather radar AND Flight crew fail to visually acquire obstacle and rectify in time	1 x 10^{-3} (note 1) 1 x 10^{-5} (note 2) 1 x 10^{-1} (note 2) **Total: 1 x 10^{-9}**
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	Obstacle present without vertical separation AND The obstacle is missing from the weather radar display AND Flight crew fail to visually acquire obstacle and rectify in time	1 x 10^{-3} (note 1) 1 x 10^{-5} (note 3) 1 x 10^{-1} (note 2) **Total: 1 x 10^{-9}**
Note 1: Assumed - see 4.2.8. Note 2: Assumed - see 4.2.5. Note 3: Assumed - see 4.2.2.		

4.5.4 Risk tolerability

4.5.4.1 Table 14 shows a summary of conflict scenario 3, based on the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 14 Summary of Conflict Scenario 3

Conflict Scenario 3: The helicopter comes into conflict with another obstacle			
	Severity	**Probability**	**Result**
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE

4.5.5 Sensitivity analysis and mitigations

4.5.5.1 For conflict scenario 3a and 3b to become NEGLIGIBLE, the overall probability would have to reduce by a factor of at least 100. It is unlikely this could be achieved with existing equipment and standards since there are no obvious mitigations available.

4.5.5.2 However, the maritime Automatic Identification System (AIS) that is now deployed on large[1] vessels transmits the vessel's location and identity via datalink. This information could be integrated into the helicopter displays so that large obstacles would be shown on the navigation display. While not intended as an aviation obstacle avoidance system, this would provide further safeguard against this conflict scenario by providing a cross-check against weather radar.

4.6 Conflict Scenario 4: Helicopter comes into conflict with the destination installation

4.6.1 Description

4.6.1.1 In this scenario the helicopter comes into conflict with the destination installation during the approach or overshoot. The conflict may be caused through flight crew error or equipment failure.

4.6.1.2 This scenario is similar to conflict scenario 3 except that the approach and overshoot paths must be clear of all other obstacles but the destination is always present. This conflict scenario can occur where there is a discrepancy between the actual position of the installation relative to the helicopter and where the flight crew believe it to be located.

4.6.1.3 The following hazards have been identified that could cause this conflict scenario, namely:

- ID1: Weather radar displays incorrect information. For example, the display could 'paint' the installation in the wrong place causing the helicopter to come too close to the installation.
- ID6: Wrong wind or other information from installation. Incorrect wind information could cause the helicopter to approach with an unexpected cross-wind. This ought to be detected by the need for the helicopter to continually adjust its heading. But if it wasn't it could result in the helicopter turning the wrong way at the OIP and coming closer than anticipated to the rig.
- ID8: Incorrect equipment operation/selection. For example, incorrect range setting on the weather radar could cause the helicopter to come closer than expected to the installation.
- ID9: Flight crew error, through distraction/inattention/disorientation.

4.6.1.4 As with conflict scenario 3, an incorrect range setting on the weather radar can increase the minimum detection range, thus preventing display of the destination. Incorrect tilt setting could also affect the display of the destination, e.g. due to over-scanning. In addition, precipitation and/or high sea states could cause clutter on the radar display that could make the destination more difficult to identify.

4.6.1.5 Another potential cause of this conflict scenario is pitch-up, which could cause the obstacle to disappear from the weather radar display. An example of this is given in CHIRP 4. Radar scanner stabilisation should prevent this occurring and is normally activated. Note that significant pitch-up is most likely to occur when slowing down after visual acquisition, which is during the visual segment of the approach on completion of the ARA.

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[1] The relevant IMO requirement is for all ships over 300 gross tonnes on international voyages to carry AIS equipment. It is not clear how far this applies to vessels such as crane barges, but national administrations can extend this requirement to cover such vessels.

4.6.2 Severity

4.6.2.1 The conflict scenario can arise in two ways:

- The helicopter comes into conflict with the destination installation due to flight crew error, e.g. the flight crew miss-locate the destination on the display due to clutter (ID7) or due to distraction/inattention/disorientation (ID9), the probability of both of which can be increased by miss-setting of the weather radar controls (ID8).
- The helicopter comes into conflict with the destination installation due to failure of the weather radar to display the installation in the correct location, e.g. due to unannunciated failure of the weather radar (ID1).

4.6.2.2 The chain of events that is required to generate either of these two outcomes is presented in Table 15.

Table 15 Chain of events causing Conflict Scenario 4

Event	Hazardous chain of events	Severity
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	Flight crew miss-locate installation on display AND Flight crew fail to see installation and avoid in time AND Some part of installation in helicopter path.	CATASTROPHIC
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	The weather radar displays installation in incorrect location AND Flight crew fail to see installation and avoid in time AND Some part of installation in helicopter path.	CATASTROPHIC

4.6.3 Probability

4.6.3.1 Table 16 shows a summary of the probabilities associated with each of the events.

Table 16 Probability analysis for Conflict Scenario 4

Event	Hazardous chain of events	Probability
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	Flight crew miss-locate installation on display AND Flight crew fail to see installation and avoid in time AND Some part of installation in helicopter path.	1×10^{-3} (note 1) 1×10^{-1} (note 1) 1×10^{-2} (note 2) **Total: 1×10^{-6}**
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	The weather radar displays incorrect information AND Flight crew fail to see installation and avoid in time AND Some part of installation in helicopter path	1×10^{-5} (note 3) 1×10^{-1} (note 1) 1×10^{-2} (note 2) **Total: 1×10^{-8}**
Note 1: Assumed - see 4.2.5. Note 2: Assumed - see 4.2.9. Note 3: Assumed - see 4.2.2.		

4.6.4 Risk tolerability

4.6.4.1 Table 17 shows a summary of conflict scenario 4, based on the modified AMJ25-1309 risk acceptability criteria (see the study approach in Section 2 of the main report).

Table 17 Summary of Conflict Scenario 4

Conflict Scenario 4: The helicopter comes into conflict with the destination installation			
	Severity	**Probability**	**Result**
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	CATASTROPHIC	REMOTE	UNACCEPTABLE
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	CATASTROPHIC	EXTREMELY REMOTE	UNACCEPTABLE

4.6.5 Sensitivity analysis and mitigations

4.6.5.1 For conflict scenario 4a to become TOLERABLE, the overall probability would have to reduce by a factor of at least 1000. For example, the probability of some part of the installation being in the helicopter path would have to reduce from 10^{-2} to 10^{-5}. For conflict scenario 4b to become TOLERABLE, a reduction in probability by a factor of 10 would be required.

5 Conclusions and recommendations

5.1 Conclusions

5.1.1 Table 18 summarises the results of the conflict scenario analysis.

Table 18 Summary of Conflict Scenarios

Conflict Scenario 1: The helicopter approaches the wrong installation			
	Severity	**Probability**	**Result**
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	CATASTROPHIC	EXTREMELY REMOTE	UNACCEPTABLE
Conflict Scenario 2: The helicopter comes into conflict with the sea			
	Severity	**Probability**	**Result**
2a. The helicopter comes into conflict with the sea due to crew error.	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE	NEGLIGIBLE
2b. The helicopter comes into conflict with the sea due to altimeter failure	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
Conflict Scenario 3: The helicopter comes into conflict with another obstacle			
	Severity	**Probability**	**Result**
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	CATASTROPHIC	EXTREMELY IMPROBABLE	TOLERABLE
Conflict Scenario 4: The helicopter comes into conflict with the destination installation			
	Severity	**Probability**	**Result**
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	CATASTROPHIC	REMOTE	UNACCEPTABLE
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	CATASTROPHIC	EXTREMELY REMOTE	UNACCEPTABLE

5.2 Recommendations

5.2.1 Paragraph 3.9.3 states that current ARA procedures are inconsistent between operators, which makes it harder to ensure consistent levels of safety. It is recommended that the procedures are harmonised through discussions with operators and manufacturers. Particular areas which do not appear to be sufficiently covered by existing standards include:

- Weather radar tuning since there is no 'right answer'. Pilots adjust the equipment to gives the best results and specific training or guidance may be beneficial.
- Use of autopilot where available. This is a type-specific issue that need to be addressed for each helicopter type.

5.2.2 Section 4.4.5.2 identifies that hazards in conflict scenario 2b may be mitigated by installing a second radar altimeter to provide a continuous cross-check against the first. It is recommended that this is investigated further.

5.2.3 Section 4.5.5.2 notes that use of the maritime AIS could improve the results for conflict scenarios 3a and 3b by providing an independent (to the helicopter’s weather radar) means of locating obstacles in the approach and go-around paths.

6 References

[1] "Minimum Operational Performance Standards for Airborne Radar Approach and Beacon Systems for Helicopters", RTCA DO-172, 19 November 1980.

[2] "Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radars", RTCA DO-173, 19 November 1980.

[3] "Airborne Weather Radar Equipment", TSO-C63b, Department of Transportation, FAA.

[4] "Airborne Weather and Ground Mapping Pulsed Radars", TSO-C63c, Department of Transportation, FAA, 18 August 1983.

[5] "Airborne Low-Range Radio Altimeter", TSO-C87, Department of Transportation, FAA, 1 January 1966.

[6] "Airborne Radar Approach and Beacon Systems for Helicopters", TSO-C102, Department of Transportation, FAA, 2 April 1984.

[7] "Approval of Offshore Standard Approach Procedures, Airborne Radar Approaches, and Helicopter En Route Descent Areas", AC 90-80B, Department of Transportation, FAA,
12 April 1999.

[8] "Support to GNSS Research Programme: RNAV-GNSS Risk Register", Helios Technology, Reference P340D001, 24th June 2003.

[9] JAA, System Design and Analysis, Change 14 Joint Aviation Authorities Doc. JAR-25, Section 3: Advisory Material Joint, Doc. AMJ25.1309, including Change 15, 1 October 2000.

[10] "The use of GPS for en-route offshore helicopter operations - Hazard analysis", Helios Technology, P416D003 v2.0, 29 June 2005.

[11] "Hazard Analysis of Route Separation Standards Rev. 3 for EUROCONTROL", DNV TECHNICA, Contract No. C/1.201/HQ/DT/94, May 2006.

[12] "Software Considerations in Airborne Systems and Equipment Certification", RTCA DO-178B, 1992 (errata issued 1999).

[13] "Environmental Conditions and Test Procedures for Airborne Equipment", EUROCAE ED-14c (now superseded).

[14] "Airborne Automatic Direction Finding (ADF) Equipment", TSO-C41d, Department of Transportation, FAA, May 1985.

[15] "Environmental Conditions and Test Procedures for Airborne Equipment", EUROCAE ED-14b (now superseded).

[16] "MPS for Airborne ADF Equipment", EUROCAE ED-51, 1983.

[17] "Environmental Conditions and Test Procedures for Airborne Electronic/ Electrical Equipment and Instruments", RTCA DO-138 (now superseded by DO-160/ED-14).

[18] "Airborne Radar Approach, FAA/NASA Gulf of Mexico Helicopter Flight Test Program", ADA085481, D P Pate and J H Yates, FAA, 1980.
http://stinet.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA085481

Part 2, Annex A ARA equipment and maintenance procedures

A.1 Introduction

A.1.1 This section presents a summary of the helicopter equipment used during the ARA procedures. The certification standards applicable to the equipment and the equipment maintenance procedures are also given. Further details of some of the equipment types are given in Annexes E through H.

A.1.2 It was considered neither necessary nor practical to research all of the equipment types listed here in detail. The analysis was based on a few representative systems and, specifically, the Bendix RDR-1400 weather radar which is widely used. When an operator is approved for ARA procedures, the specific equipment used will need to be considered.

A.2 Current systems in use

A.2.1 Table 19 summarises the ARA-related equipment on-board North Sea helicopters (data was supplied by CHC Scotia Helicopters, but is also applicable to other operators). The systems that support the ARA include:

- Weather radar.
- Barometric altimeter.
- Radio altimeter.
- ADF.
- Displays.
- Compass.

Table 1 On-board equipment supporting ARA

Aircraft	Weather Radar	Barometric Altimeter	Radio Altimeter	ADF	Displays	Compass
365N	Honeywell Primus 500	Badin Crouzet	Thales TRT AHV8	Collins ADF60	Electro-mechanical	SFIM CG130
365N2	Bendix RDR 1400	Badin Crouzet	Thales TRT AHV8	Collins ADF60	Electro-mechanical	SFIM CG130
S76A+	Bendix RDR 1400	Thommen	Collins ALT 50	Collins ADF60	Electro-mechanical	Honeywell C14A
S76C	Bendix RDR 1400	Aerosonic	Collins ALT 50	Collins ADF60	Electro-mechanical	Honeywell C14A
332L	Honeywell Primus 500 or Bendix RDR 1400	Badin Crouzet	Thales TRT AHV8	Collins ADF60	Electro-mechanical	SFIM CG130
332L2	Bendix RDR 1400C	Thales Air Data Computer, info displayed on IFDS	Thales TRT AHV16	Collins ADF462	Thales "Integrated Flight and Display System" (IFDS) CRTs	Thales Flight Data Computer
S92	Honeywell Primus 700	Rosemount 2017A Air Data Computer, info displayed on EFIS	Honeywell AA300	Collins ADF462	Rockwell Collins AMLCD EFIS	Litef 92S AHRS
AB139	Honeywell Primus 660 or 701	Honeywell Air Data Module, info displayed on EFIS	Honeywell AA300	Honeywell DF855	Honeywell Primus EPIC EFIS	Litef AHRU
EC225	Bendix RDR 1400C	Thales ADU 3000 Air Data Computer, info displayed on EFIS	Thales TRT AHV16	Collins ADF462	Thales AMLCD Flight Display System	Thales APIRS F201 computer including AHRS
EC155	Bendix RDR 1400C	Thales ADU 3000 Air Data Computer, info displayed on EFIS	Thales TRT AHV16	Collins ADF462	Thales AMLCD Flight Display System	Thales APIRS F201 computer including AHRS

A.3 Equipment standards

A.3.1 Information on equipment standards has been obtained through consultation with the helicopter operators and equipment manufacturers.

A.3.2 Information received from Telephonics[1] on the RDR-1400 indicates that this weather radar is certified and manufactured to the following standards:

- FAA TSO-C63b [3].
- FAA TSO-C102 [6].

A.3.3 Further information provided by Telephonics is summarised in Annex E.

A.3.4 Information obtained from Honeywell on the Primus 700 indicates that this weather radar is certified and manufactured to the following standards:

- FAA TSO-C63b [3].
- FAA TSO-C102 [6].
- RTCA DO-178B [12] Level B.

A.3.5 Information obtained from Rockwell Collins on their products indicates that these are certified and manufactured to the following standards:

- Collins ALT 50
  - FAA TSO-C87 [5].
  - EUROCAE ED-14c [13].
  - RTCA DO-178B [12] Level A.
- Collins ADF 462
  - FAA TSO-C41d [14] (Class A).
  - EUROCAE ED-14b [15].
  - EUROCAE ED-51 [16].

A.3.6 The Thales TRT AHV8[2] radio altimeter is certified to RTCA DO-138 [17] which has been superseded by DO-160/ED-14.

A.4 Maintenance procedures

A.4.1 Maintenance procedures performed by the operators follow the requirements of JAR-OPS 3 Subpart M and JAR 145. The JARs stipulate maintenance according to the regime specified by the equipment manufacturer or as agreed by the aircraft operator with the regulator.

A.4.2 All repair and maintenance is conducted by the operator, or a designated repair facility or the equipment manufacturer. In any case, the repair is conducted by an organisation approved according to the requirements of EASA Part-145 and FARs Parts-145 and 43. These regulatory requirements mandate that the repair facility have:

- All equipment necessary to carry out the repair.
- Correct facilities in which to carry out the repair.
- All required updated equipment manuals to diagnose and repair faults.
- All technical data related to faulty equipment and replacement parts.
- Training records for all repair personnel.

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[1] Telephonics now own the RDR-1400 brand, not Bendix.

[2] The TRT AHV8 radio altimeter is now available through Thales as the Thales AHV8. The radio altimeter models are referred to as the LRRA (Low Range Radio Altimeter) AHV Family and may be prefixed ERT.

A.4.3 The maintenance schedule presented in Table 20 summarises CHC Scotia's procedures.

Table 2 Maintenance procedures

Weather Radar	On condition plus comprehensive check every 2 years.
Barometric Altimeter	On condition plus calibration every 2 years.
Radio Altimeter	On condition.
ADF	On condition plus calibration swing every 2 years or on change of components or major modification to aircraft.
Displays	On condition.
Compass	On condition plus calibration swing every 2 years or on change of components or major modification to aircraft.

A.4.4 Bristow Helicopters have indicated that their weather radar maintenance procedures are in accordance with the manufacturer specified 'installation' check.

A.4.5 Aircraft manufacturers may specify maintenance schedules in addition to those specified by the weather radar manufacturers. However, all weather radar maintenance follows the procedures specified by the radar manufacturers. These procedures include requirements for installation, post installation checks, pre-flight checks and in-flight checks of the system.

A.4.6 Maintenance requirements specified by the aircraft manufacturers call for an antenna inspection every 2 years or 750 hours (whichever is earlier). The inspection of the antenna is a visual inspection to ensure that the driving motors and return springs, where fitted, are operational and free running. Further inspections at different intervals are stipulated to replace antenna bearings as directed by the aircraft manufacturer.

A.4.7 All other maintenance performed on the weather radar is 'on condition', i.e. when the flight crew report a fault with the equipment.

A.4.8 As noted by CHC Scotia the radio altimeter equipment is only maintained 'on condition'. The built-in system checks are very thorough and modern radio altimeters are extremely sophisticated requiring specialist tools to diagnose faults. Increasingly the radio altimeters are based on software processors that log all faults which can be downloaded to a computer and analysed as part of the repair diagnosis.

A.5 Pre-flight test procedures

A.5.1 On board maintenance procedures for helicopters are covered by the requirements of JAR OPS 3 Subpart M and JAR 145.

A.5.2 In this respect, AMC OPS 3.890(a)(1) (describing "Maintenance Responsibility") details some of the steps required by the pre-flight inspection. In particular it calls for the flight crew to receive guidance on how to perform the pre-flight visual inspection checks of:

- A walk-around inspection of the helicopter and its emergency equipment for condition.

- Inspection of the Technical log to ensure that the intended flight is not adversely affected by any outstanding defects and that no required maintenance action shown in the maintenance statement is overdue or will become due during the flight.
- That consumable fluids, gases etc. uplifted prior to flight are of the correct specification, free from contamination and correctly recorded.
- That all doors are securely fastened.
- Control surfaces and landing gear locks, pitot-static probe covers, restraint devices and engine/aperture blanks have been removed.
- That all the helicopter's external surfaces and engines are free from ice, snow, sand, dust etc.

A.5.3 However, it is noted that no visual inspection of the weather radar system is called for within JAR-OPS 3, it being the responsibility of the operator to decide whether such a check is required.

A.5.4 Additionally, it is noted in AMC OPS 3.890(a)(2) that:

> "The Operator should have a system to ensure that all defects affecting the safe operation of the helicopter are rectified within the limits prescribed by the approved MEL or CDL as appropriate and that no postponement of such a defect rectification can be permitted unless with the Operator's agreement and in accordance with a procedure approved by the Authority."

A.5.5 Table 21 summarises CHC Scotia's on-board test procedures performed by the aircrew..

Table 3 Test procedures

Weather Radar	Built In Test function and normal operational use.
Barometric Altimeter	Pre-flight cross-check of all barometric altimeters to be within 50 feet of airfield elevation. Further cross-checks in flight at all level changes and on approach. For offshore approaches, additional cross-checks with radio altimeter.
Radio Altimeter	Pre-flight test (indicates 100 feet) and check of aural Decision Height and 100 Feet warnings.
ADF	Pre-flight check of tuning and correct identification of beacon with sensible bearing indications. Repeated in flight for all new NDB signals including installation NDBs.
Displays	On condition in normal operational use.
Compass	Pre-flight and in-flight cross-checks of main compasses against standby compass and known (approximate) heading.

A.5.6 Bristow Helicopters have indicated that their maintenance procedures are similar to those employed by Scotia.

A.5.7 Bond Offshore Helicopters have indicated that an in-flight check of the weather radar system is performed after the helicopter is airborne. The system is switched on and any failure conditions are indicated to the flight crew through system messages on the weather radar display.

A.5.8 Onboard installation checks are also required in accordance with the equipment manufacturer's maintenance requirements. In normal practice, installation checks are completed following installation of equipment that is either drawn from stores or 'robbed' from another aircraft.

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Part 2, Annex B CHIRP Events

B.1 Introduction

B.1.1 This section summarises CHIRP events related to offshore approaches. Some of these reports were filed before the ARA minima were increased in the mid-1980s, and so are presented to illustrate potential problems rather than as statistical evidence.

B.1.2 Some CHIRP reports describe incidents where the rules or procedures have been deliberately broken. While it is inappropriate to use these as evidence of weaknesses in the current ARA procedure, it is judged likely that there would be fewer such incidents if an instrument approach procedure were available.

B.2 CHIRP 1

B.2.1 The type of approach being made was a radar/NDB approach. The weather reported by the installation was 300 ft cloud base and about 3/4 NM visibility, wind calm. The sea was as calm as a millpond and the surface like a mirror. Other helicopters had already made successful approaches and landings in the same vicinity. On reaching our minimum descent height we could see the surface, but forward visibility was nil as we were still marginally inside the cloud base. Knowing that if we overshot on the approach we would have to go to our diversion, I told the co-pilot that I was resetting my radio altimeter warning light "bug" 50 feet lower and continuing to descend. Almost immediately thereafter we saw the installation about 1/2 mile ahead in haze with no discernible horizon. I ceased to scan the instruments for a few seconds while looking at the installation to assess how best to make a landing. **Shortly the co-pilot warned me that we had descended below 50 feet and I am still shocked at how quickly I descended so low without perceiving it.**

B.2.2 Hazard: Pilot descended below MDH.

B.3 CHIRP 2

B.3.1 I was the captain of a helicopter flight to an offshore oil platform. The weather forecast indicated the presence of low stratus and shortly before we arrived the oil platform went into fog. I elected to conduct a NDB plus Weather/Mapping radar approach to the destination. Now, my co-pilot was relatively new to the North Sea and having demonstrated the approved approach technique to him in VMC just two days prior, I was determined to show him that in the real situation I followed the exact same procedure and resisted the temptation to "grobble" in visually at low speed.

B.3.2 With the co-pilot handling the controls and flying on instruments and myself monitoring the profile, we descended to the MDA of 170' radar altimeter at approximately one and a half NM and continued the run in to Decision Range of 0.5NM. The aircraft was flown at the approach speed of 75 kts and the approach was into the light wind reported at 10 kts. I could see the surface but there was no horizon and forward visibility very poor.

B.3.3 I was conscious of a nagging doubt about the procedure which I had demonstrated so confidently in VMC. How much off the nose should I put the radar blip? Too little and the oil platform, a large 300' to 400' high structure would be right in front and above us at less than half a NM while we closed at 60 kts ground speed. Too much offset and I would pass abeam the platform by such a distance that I could not hope to see it.

B.3.4 The radar painted the target only every 5 secs and as the platform's blip approached the bottom of the screen I wondered if there was a blank space in the radar display into which the blip could disappear without ever getting to the declared minimum range, in which case each successive sweep would just shave off the leading edge of the blip so that it never got any closer. However, the approach continued normally and I wanted to demonstrate the importance of adhering to approach procedures.

B.3.5 At the minimum range of 0.5 NM, the offshore structure was not in sight and I called for the turning missed approach procedure to be executed. As we turned away and climbed I was shaken to see the oil platform in a twenty-degree bank suddenly appear in the 1 o'clock, hurtle down the starboard side and be passed before I could even squeak.

B.3.6 In retrospect I think that this experience warranted an MOR as it indicated that the procedure might be unsatisfactory and the limits too low. However, it is worth noting that in my company the pilots do not have direct access to the relevant MOR forms. Another factor which might bear investigation is that **there appears to be no provision in the aircraft maintenance schedules for calibration of the all important airborne radar.**

B.3.7 Hazard: Approach too close to installation (horizontal minima now changed).

B.4 CHIRP 3

B.4.1 I was giving retraining to experienced North Sea Helicopter Captain. Although platform was giving very poor visibility I decided to make an approach (NDB/RADAR) down to .45NM @ 150' (other Captain handling) to give him experience. I pointed out to him the fact that provided the approach pattern was followed to the letter there was no problem and when/if we overshot we would divert to Unst. Approach was flown "perfectly" but I was slightly alarmed to see a platform light pass quite close underneath and to one side in the fog during overshoot. Procedure has now been modified.

B.4.2 Hazard: Approach too close to installation (horizontal minima now changed).

B.5 CHIRP 4

B.5.1 We were making an installation Radar/NDB approach to a semi-submersible. The installation had been in fog that morning, but prior to our departure, the fog had lifted into low stratus and was beginning to disperse. Since the wind direction was such that the helideck would be on our starboard side, I elected to fly the approach and have the co-pilot carry out the landing. By 150 feet on Radalt we were down to 70 knots IAS and running in to a decision range of 0.5 NM, visual with the surface. Shortly after the co-pilot called "One mile", I briefly looked across at the Radar screen and saw the return at 0.7 NM.

B.5.2 On looking back at the Radalt, I found that the height had increased by about 25 feet, as I'd inadvertently allowed the nose to come up a few degrees. At the same time, the co-pilot called that he had lost Radar contact with the installation. Believing that this might be due to the increased nose-up attitude, I quickly adjusted the tilt of the antenna down a few degrees, convinced that the installation would reappear at just over half a mile. It did not. I called "Overshooting" and commenced a climbing turn away from the location. Several seconds later, the co-pilot called that he was visual with the derrick out to the left, through the broken stratus. The distance was difficult to estimate, but the installation looked too close for comfort.

B.5.3 Hazard: Approach too close to installation (horizontal minima now changed).

B.6 CHIRP 5

B.6.1 The "TOO CLOSE FOR COMFORT" article in the number 10 issue of Feedback prompts me to write to you about an experience I had during an approach to an offshore oil platform.

B.6.2 I was the Commander of the helicopter and my co-pilot was also an experienced North Sea Captain. This particular day the weather forecast indicated deteriorating visibility but we were carrying plenty of fuel and it did not give us any cause for concern. When we made radio contact with the platform we discovered that the weather was in fact much worse than initial reports had indicated. The cloud base was estimated as 500ft with visibility at 1-2 NM and signs of fog patches forming. I elected to carry out a radar/NDB approach.

B.6.3 From the wind direction we had been given it was clear that my co-pilot would have to carry out the actual landing so I flew the procedure while he kept visual lookout. We descended towards the platform and found the cloud base to be 300ft and not very well defined, but we did establish good visual contact with the sea surface and the descent was continued. The forward visibility was about 1 NM but less than that in patches. My co-pilot read off the ranges to go from the radar and at .75 NM announced that he could see the outline of the platform. At .5 NM he had firm contact and I handed over control to him for the landing.

B.6.4 On looking up to get my own visual bearings I was a little unnerved to see how close we were to such a large structure, a feeling I had experienced before. The helideck was at a height of 230ft above the sea surface so it was obviously necessary to climb to get on to it. Imagine our horror when on initiating this manoeuvre the platform promptly disappeared from view. I ordered an immediate overshoot at maximum power. I found my hands instinctively going to the controls and I had to force myself to allow my perfectly competent co-pilot to continue handling the aircraft while I carried out the checks and monitored the flying. How close did we get to the platform? I hate to think!

B.6.5 After we had settled down at a safe height and discussed the problem I chose to make another approach but this time we would not descend below the height of the helideck. When we made visual contact from that approach we knew that we could carry out the landing without having to climb and that is what we did, this time without frightening ourselves.

B.6.6 Hazard: Approach below deck height (vertical minima now revised).

B.7 CHIRP 6

B.7.1 The decision that the captain should handle the aircraft himself while the co-pilot would operate the radar and give the talk own was taken purely on the basis of who would be sighted for the actual touchdown. Perforce, the co-pilot would make all the decisions as to the safety of the approach track and in particular the co-pilot would make the command decision, whether to execute the Visual Landing Manoeuvre (VLM) or order an overshoot. These decisions cannot normally be left to a co-pilot, they are "COMMAND DECISIONS".

B.7.2 The co-pilot does not seem to have been providing a very comprehensive talk-down; he called, "One mile" and later that the target had been lost.

B.7.3 Because of a vague awareness of his command responsibility and the inadequate nature of the co-pilot's talk-down, the captain felt it necessary to break his instrument scan and look across at the radar. The result was predictable, his height keeping suffered and this when the aircraft was at 150ft in very poor visual conditions. (Refer to the Scillies disaster, G-BEON 1983). When the target was reported as lost, the captain did not act on what he had been told, but chose to adjust the radar himself. (Question: What was the height keeping like during this phase?)

B.7.4 The close fly-by of the installation probably resulted from a late turn-away and a procedure which in all likelihood had a 10% chance of hitting the installation anyway!

B.7.5 The lessons to be learned are as follows:-

- In all normal circumstances, the captain must operate the radar, assess the progress of the approach and give a positive talk-down with command instructions.
- The captain must make all executive decisions, especially whether a VLM is to be executed or an overshoot ordered.
- If the captain will be un-sighted for the touchdown, then the co-pilot will need to be briefed to the effect that he will be required to complete the last 100 metres and 50ft of the VLM.
- The handling pilot must not break his instrument scan in order to look at the radar nor attempt to operate the radar himself. He must execute all reasonable instructions in the talk-down, and when told to overshoot, he should execute the Missed Approach promptly.

B.7.6 It is interesting to note that the close encounter with the installation occurred several seconds after the Missed Approach was initiated. By analogy, in a motorway pile-up, we will all have been standing on the brakes for some time before our respective impacts!

B.7.7 Hazard: Miscommunication between crew.

B.8 CHIRP 7

B.8.1 Reference your note regarding my CHIRP. I agree the decision range for a radar approach has recently been increased from one half NM to three quarters NM. However the instance I outlined in my report occurred at between one NM and three quarters NM indicated radar range and we almost hit the installation. So the simple answer to your question is yes such near misses will still occur. To be honest it is a miracle that a helicopter has not hit a installation using this procedure. I suppose we must be thankful for small mercies. Personally I feel approval of this procedure by the CAA was an act of gross criminal negligence and that they should be taken to task over it. The lives of thousands of people have been put in serious jeopardy by sheer complacency.

B.8.2 It is ridiculous, even now, that the procedure is still being used because the Flight Manual supplements state categorically that the WX radar MUST NOT be used for collision avoidance. The radar accuracies are not published, they are not calibrated and the manufacturers do not know how accurate they are because they were not designed for collision avoidance in the first place. The procedure has been flown down to minima which equate to minima for precision approaches to land airfields. Now I ask you what self respecting authority would allow you to carry out an ILS using uncalibrated ground or airborne equipment. Well that is what has been and still is happening in the offshore helicopter industry.

B.8.3 As you will have gathered I feel pretty strongly about this subject but there are numerous other areas e.g. offshore alternates, Low Vis ILS etc. which have been approved along similar lines to radar approaches i.e. unscientifically by pressure on the CAA from sharp helicopter operators who can gain a commercial advantage with reduced minima or being able to carry less fuel therefore more payload. Unfortunately this commercial advantage is short lived as all the others apply for and generally get the reduced minima etc. This leads to a downward spiral and gradually erodes safety margins until they become unacceptably low. The North Sea has reached this state and something has to be done soon. The responsibility lies fairly and squarely on the shoulders of the CAA. If they continue to shirk their responsibility I dread to think what the consequences will be.

B.8.4 Hazard: WX radar not calibrated.

B.9 CHIRP 8

B.9.1 Whilst planning an 0645 Local flight to a platform in the Northern North Sea the area forecast had been compiled the previous evening, no TAF or ACTUAL was available for the closest and usual diversion. There was an ACTUAL available for airfields close by but no TAF. The Sea Area TAF and area forecast gave low cloud mist and drizzle with a low probability of fog. As the En Route Airfield TAF + ACTUAL were reasonable I elected to update the Met on arrival.

B.9.2 On departure 0815L the platform was giving 8K 8/8 above 1000ft. A gut feeling made me increase the fuel above the minimum which gave an airfield diversion from the En Route and a little spare on the legs out and back to the platform. On arrival at the En Route the closest diversion TAF + ACTUAL, another TAF and update from the platform were available.

B.9.3 As the land was covered in cloud over the hills with a 160 degree wind and the usual diversion temp + dewpoint both +12 I elected to take the TAF with a pinch of salt luckily the other airfield was OK. But the platform was now giving 1NM viz 8/400. When we got VHF contact they gave 1-3/4NM 8/300. But they had a casivac who required emergency surgery.

B.9.4 Before the approach I asked the standby boat to check the WX 3/4 mile with cloud just clear of the helideck (HT 200ft). I monitored the co-pilot on the approach. At 2NM and 250ft I could clearly see the surface. Always a good sign. At one and a half NM and 200ft (MDH) I could see the surface but we were still in the base of cloud. Descended to 150ft and gained forward viz at 1NM. At 3/4NM (MAP) no contact with platform but I was satisfied that with the ground speed we were flying there was sufficient visual distance for a manoeuvre to clear it.

B.9.5 Below 3/4NM the radar distance became impossible to judge but we became visual with the support vessel and then the platform at I guess 600 metres with the deck in the cloud base. Care was needed in avoiding re-entering IMC. The casualty was successfully taken to hospital. At no time during the approach did I feel that we were taking an undue risk. With the power being used we were well inside single engine power except possibly for the actually moving onto the helideck. But this is not unusual during a installation landing.

B.9.6 Throughout the approach the co-pilot flew accurately and all aids and instruments cross checked correctly. Despite the TAF the area remained in fog for the majority of the day. Although in this case the need to carry out the casivac was relevant a number of points are worthy of thought:

- It is not sensible to plan flights on a regular basis without all the necessary Met data being available and current. As happens at present.
- The North Sea operation relies heavily on the quality of Met forecasting and its method of dissemination for the whole area including the island and coastal airfields. Both these often, and particularly early in the morning and at weekends, leave a lot to be desired.
- I have flown in both crew positions in similar conditions before in the full knowledge that we have been below published minima but the pressure to continue when in contact with the surface with forward visibility towards an installation where a refuel is possible is great when compared to a diversion on minimum fuel to alternate that may be unfamiliar and affected by the same weather system as the installation. Changing the minima (i.e. the MDH for this approach had been 150ft for a period a few years ago) only increases the pressure on the crew as they consciously break the rules more readily.
- In my experience crews tend to make the same judgement as to what conditions to continue the contact phase of flights in and use similar criteria to achieve this. Safety would be increased if the cockpit workload during this phase of flight was reduced by the statutory provision of technological aids. Reply to our note rcvd 27.09.89 says "I am old, and thick skinned enough not to care too much if you transmit it on BBC1!" REPORT SENT TO CAPT RAMSDALE HD FLT OPS DEPT 2 REPLY DD 12.10.89 RCVD 12.10.89 ATTACHED

B.9.7 Hazard: Crew breaking minima.

B.9.8 Hazard: Poor quality of Met data.

B.10 CHIRP 9

B.10.1 We are tasked to fly a relatively short offshore passenger sector at night. The weather at ### (point of departure) was clear but the weather at the ### (destination installation) was reported as "not good". There are no trained Met observers on ### (destination installation).

B.10.2 The transit flight was normal, we planned a installation radar approach starting our descent into wind at 4 NM from 1,200ft. The helideck orientation dictated a Left Hand Seat landing. As Captain (RHS) I flew the approach intending to hand-over to the co-pilot for the actual landing.

B.10.3 The approach proceeded as expected. The weather was not good, low cloud base and fog patches. At our MDH of 300ft (night) we were in the bottom of broken cloud. At decision point of 0.75 NM, 300ft offset from our approach track by 15 deg the co-pilot indicated he had lights visual and to continue.

B.10.4 I descended a further 50' to 250' and at approx 1000 metres the co-pilot indicated he was happy to take control of the landing. As soon as control was transferred, I called height and airspeed continually. I could see the lights of the installation in my peripheral vision and at approx 800m and 250ft with 50kts IAS I glanced up at the installation. As I looked down the AVAD 100' warning activated and the rad alt showed us descending through 100'. Corrective action had been instigated by the co-pilot, the AVAD warning was verbally acknowledged by us both. I continued calling height and airspeed, the a/c levelled at 50ft and 45kts. There was more power available and I called for it to be applied. The a/c climbed away and at 250ft 60kts we were 300m from the installation, the helideck was clearly visible the windsock on the nearest crane confirmed the wind (Southerly 15kts), which gave us an unobstructed landing.

B.10.5 We continued the approach and the landing phase was normal and smoothly flown.

B.10.6 Discussing the incident after the flight, the co-pilot felt he had inadvertently descended too low because of the visual cues he was getting from the platform lights. I will add that in addition the safety vessel that was in close proximity to the platform was more brightly illuminated (it was a supply vessel equipped with floodlights) and was rising and falling in the swell.

B.10.7 I felt this incident would not have occurred if I had flown the a/c on instruments monitored by the co-pilot until we were much closer to the platform with the helideck clearly visible before handing over to the landing pilot as an S.O.P or if the a/c had been fitted with rad alt height hold.

B.10.8 I wonder how many others have found themselves in a similar situation on a night approach to a installation in bad weather who also have had a "fortunate outcome".

B.10.9 Hazard: Inadvertent descent below MDH.

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Part 2, Annex C HOMP Events

C.1 Introduction

C.1.1 This section lists HOMP events related to offshore approaches.

C.2 HOMP 1

C.2.1 The HOMP detected a go-around flown offshore in bad visibility following an ARA because the selection of "bleed offset" fortuitously generated a 'torque split in the cruise' event. Following visual contact with the platform at low level, the aircrew had inadvertently climbed 50 ft, which put them into cloud approximately 0.2 NM from the platform. Flying low and slow in cloud close to the platform presented a hazard and the aircrew took the right corrective action and performed a go-around. BHL's HOMP Manager gave the crew a disk containing the data and FDS program for them to review, and recommended that they raised an ASR. It could clearly be seen that the problem had occurred when the aircraft slowed to below minimum drag speed. The pilot correctly applied power to arrest the deceleration and prevent a descent, but overdid it and the aircraft climbed as a result.

C.2.2 Hazard: Helicopter climbing into cloud on approach.

C.3 HOMP 2

C.3.1 Until recently, the minimum descent height in daylight for an instrument approach to an offshore installation was 200 feet. However, the current rules for an ARA specify a minimum descent height of deck height + 50 feet, but not lower than 200 feet. For the Brae Alpha, this gives a minimum descent height of 286 ft. The HOMP showed that an approach to this platform had been flown at a height of 200 feet, which decreased to a minimum of 170 feet shortly before a go-around. The HOMP Manager contacted the pilot, who accepted that his action had been incorrect.

C.3.2 Hazard: Helicopter breaking vertical minima on approach.

C.3.3 Note: This event was an intentional breaking of the minima and therefore not an accidental event.

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Part 2, Annex D MOR Events

D.1 Introduction

D.1.1 This section contains MORs related to offshore approaches. These occurrences date back to the 1970s when ARA procedures were less robust and most helicopter avionics were less sophisticated than contemporary equipment. Hence, some of the occurrences would be less likely to occur now than in the past and, therefore, cannot reasonably be used as evidence of failure rates. They are included, however, to illustrate the hazards inherent in these operations and that would need to be addressed in any new or modified procedures.

D.2 Missing or incorrect wind, pressure or weather passed to crew

D.2.1 Oil installation gave wrong surface wind direction

A/C Type :	Sikorsky S61	**Occurrence Number :**	**197601647**
Flight Phase :	Landing	**Occurrence Date :**	15 Apr 1976
Classification :	Occurrences	**Location :**	OCEAN KOK
Events :	Occurrences	**Location Info :**	

Pretitle :
Occurrence : OIL INSTALLATION GAVE WRONG SURFACE WIND DIRECTION

Precis :
WIND DIRECTION WAS 180 DEGREES OUT. THE INSTALLATION HAS NO WINDSOCK. RADIO OPERATOR HAS A WIND SPEED READ OUT IN RADIO CABIN, BUT HAS TO RING THE BRIDGE FOR WIND DIRECTION. THE MATTER HAS BEEN TAKEN UP WITH THE OIL COMPANY BY THE OPERATOR.

D.2.2 Incorrect wind passed by installation hover problems

A/C Type :	Sikorsky S61	**Occurrence Number :**	**197605128**
Flight Phase :	Approach	**Occurrence Date :**	12 Nov 1976
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrences	**Location Info :**	

Pretitle :
Occurrence : INCORRECT WIND PASSED BY INSTALLATION HOVER PROBLEMS

Precis :
THE WIND DIRECTION WAS REQUESTED THREE TIMES AND GIVEN AS NW/10KTS. AT THE END OF THE APPROACH TO A POSITION ALONGSIDE THE PLATFORM THERE WAS INSUFFICIENT POWER AND RUDDER CONTROL TO BRING THE AIRCRAFT TO A HOVER. AN OVERSHOOT WAS COMMENCED. ON THE SECOND APPROACH INTO WIND, 200/10 KTS THICK SMOKE AND TURBULENCE WERE ENCOUNTERED WHICH NEARLY CAUSED A SECOND OVERSHOOT.

CAA Closure: THE SIMRAD WIND VELOCITY MEASURING EQUIPMENT ON BOARD THIS INSTALLATION IS AWAITING REPAIR. MEANWHILE A HAND-HELD ANEMOMETER IS BEING USED FOR WIND SPEED, AND DIRECTION IS BEING ASSESSED BY THE WINDSOCK. A QUALIFIED PILOT IS RESIDENT ON BOARD.

D.2.3 Incorrect wind passed by installation handling problem

A/C Type :	Sikorsky S61	**Occurrence Number :**	**197605280**
Flight Phase :	Approach	**Occurrence Date :**	24 Nov 1976
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrences	**Location Info :**	

Pretitle :

Occurrence : INCORRECT WIND PASSED BY INSTALLATION HANDLING PROBLEM

Precis :

THE WIND PASSED BEFORE THE APPROACH WAS 340/08. DURING THE APPROACH HEAVY RAIN MADE THE ASSESSMENT OF DRIFT OVER THE SEA DIFFICULT. ON FINAL APPROACH THE AIRSPEED DROPPED OFF SHARPLY AND APPROACHING THE HOVER FELL TO BELOW 40 KTS. FULL POWER WAS REQUIRED TO CONTAIN THE SINK AND AN OVERSHOOT WAS MADE WHICH AT ITS LOWEST POINT WAS BELOW THE HELIPAD. WIND WAS ASSESSED AS 270/ 15 WHICH PUT THE BREDFORD DOLPHIN IN THE LEE OF THE PIPER PLATFORM AND THE SUBJECT AIRCRAFT IN CONSIDERABLE DOWNDRAUGHT.THE RADIO OPERATOR HAD MADE HIS OWN ASSESSMENT OF THE WIND AS THERE WAS NO WIND VELOCITY MEASURING EQUIPMENT ON BOARD.

CAA Closure: THE WIND VELOCITY MEASURING EQUIPMENT ON BOARD THIS INSTALLATION IS AWAITING REPAIR. MEANWHILE, A HAND- HELD ANEMOMETER IS BEING USED TO MEASURE WIND SPEED AND WIND DIRECTION IS BEING ASSESSED BY THE WINDSOCK ON THE HELICOPTER LANDING PLATFORM.A QUALIFIED PILOT IS RESIDENT ON BOARD.

D.2.4 Incorrect wind altimeter setting passed by installation

A/C Type :	Sikorsky S61	**Occurrence Number :**	**197704982**
Flight Phase :	Approach	**Occurrence Date :**	08 Dec 1977
Classification :	Occurrences	**Location :**	OXY VIKING
Events :	Occurrences	**Location Info :**	

Pretitle :

Occurrence : INCORRECT WIND ALTIMETER SETTING PASSED BY INSTALLATION

Precis :

CAA Closure: DISCUSSIONS WITH THE INSTALLATION OWNERS AND HELICOPTER OPERATORS IN THE PIPER FIELD ARE EXPECTED TO EFFECT AN IMPROVEMENT IN THE CONTROL OF OPERATIONS, AND AN INCREASE IN SAFETY STANDARDS.

D.2.5 Incorrect altimeter setting passed

A/C Type :	Sikorsky S61	**Occurrence Number :**	**198102967**
Flight Phase :	Approach	**Occurrence Date :**	18 Sep 1981
Classification :	Occurrences	**Location :**	OCEAN BOUNTY
Events :	Occurrences	**Location Info :**	

Pretitle :
Occurrence : INCORRECT ALTIMETER SETTING PASSED

Precis :
INSTALLATION PASSED VARIOUS UNACCEPTABLE PRESSURE SETTINGS, STATED EQUIP WAS FAULTY, THEN STATED EQUIP WAS 'S' BUT NOT CORRECTLY READ. A/C LANDED USING RAD/ALT. FIRST QFE PASSED GAVE ERROR OF 1000FT. SEE PREVIOUS OCCUR 81/1514.ALSO 81/2968,81/2969.

CAA Closure: ACTION TAKEN WITH DEPT OF ENERGY AND FLT OPS INSPECTORATE.

D.2.6 Incorrect QFE passed from oil installation

A/C Type :	Sikorsky S61	**Occurrence Number :**	**198104103**
Flight Phase :	Approach	**Occurrence Date :**	20 Dec 1981
Classification :	Occurrences	**Location :**	AUK
Events :	Occurrences	**Location Info :**	

Pretitle :
Occurrence : INCORRECT QFE PASSED FROM OIL INSTALLATION

Precis :
QFE OF 1004 PASSED, ON LANDING ACTUAL QFE WAS 998. SUSPECTED FULMAR INSTALLATION QFE PASSED IN ERROR.

CAA Closure: TAKEN UP WITH OIL COMPANY TO ENSURE INSTALLATION OPERATORS UNDERSTAND PROCS FOR PASSING ACCURATE MET INFO TO PILOTS.

D.2.7 Incorrect pressure setting passed from installation

A/C Type :	Sikorsky S61	**Occurrence Number :**	**198202363**
Flight Phase :	Approach	**Occurrence Date :**	17 Aug 1982
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	ATC Occurrences	**Location Info :**	

Pretitle :
ATC Occurrence : INCORRECT PRESSURE SETTING PASSED FROM INSTALLATION.

Precis :
UPON LANDING ON INSTALLATION, INDICATED HEIGHT WAS 400FT. INSTALLATION ASKED TO CHECK EQUIPMENT & TOLD OF DISCREPENCY. SETTINGS 10MB WRONG WERE STILL BEING PASSED.

CAA Closure: ACTION TAKEN BY OIL COMPANY.

D.2.8 Incorrect wind passed by installation handling problem

A/C Type :	Sikorsky S61	**Occurrence Number :**	**198303746**
Flight Phase :	Approach	**Occurrence Date :**	22 Dec 1983
Classification :	Occurrences	**Location :**	GLOMAR BISCQ
Events :	Occurrences	**Location Info :**	

Pretitle :

Occurrence : INCORRECT W/V PASSED TO CREW - RESULTED IN OVERSHOOT, AS A/C WAS DOWNWIND.

Precis :

PRE-FLT W/V GIVEN AS 112/20.EN ROUTE, SEDCO 700 INSTALLATION GAVE W/V 270/12-15. AT INSTALLATION DESTINATION, W/V CONFIRMED AS 090/18-20 ON INFO FROM SMALL "MODEL A/C" WIND VANE BUT, FROM FLAG ON DECK PILOT REALISED HE WAS DOWNWIND ON HIS APPROACH. A/C OVERSHOT THEN LANDED INTO WIND, HDG 270DEG.

CAA Closure: ACTION TAKEN BY INSTALLATION OPERATOR IN ISSUING PRECISE INSTRUCTIONS RE THE PASSING OF MET INFO.

D.2.9 A/C advised QFE not available prior to landing on oil installation platform

A/C Type :	Sikorsky S61	**Occurrence Number :**	**198503161**
Flight Phase :	Approach	**Occurrence Date :**	10 Sep 1985
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Occurrences	**Location Info :**	

Pretitle :

Occurrence : A/C ADVISED QFE NOT AVAILABLE PRIOR TO LANDING ON OIL INSTALLATION PLATFORM

Precis :

ACTION TAKEN WITH OIL COMPANY. RELIEF STAFF MANNING OF RADIO ROOM, UNFAMILIAR WITH PROCEDURE. PERSONNEL ACTION TAKEN.

D.2.10 Accurate wind data not available for offshore platform

A/C Type :	Sikorsky S76	**Occurrence Number :**	**200307752**
Flight Phase :	Approach	**Occurrence Date :**	06 Nov 2003
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Ground (AD) Occurrence	**Location Info :**	

Pretitle :

ACCURATE WIND DATA NOT AVAILABLE FOR OFFSHORE PLATFORM.

Precis :

SHUTTLING AT DUSK FROM THE SEAN ROMEO TO THE SEAN PAPA TO REFUEL, THE STANDBY VESSEL GAVE THE WIND AS LIGHT AND VARIABLE. THE SEAN PAPA HLO WAS ASKED FOR THE WIND DIRECTION AND REPLIED THAT, BASED ON THE WINDSOCK, HE THOUGHT IT WAS NORTHERLY. ON SHORT FINALS, AFTER COMMITTAL, IT BECAME APPARENT THAT THE WIND WAS SOUTHERLY, THE AIRCRAFT THUS LANDED DOWNWIND. THIS WAS NO PROBLEM AS THE AIRCRAFT WAS VERY LIGHT AND IT WAS STILL DAYLIGHT, HOWEVER, IF IT HAD BEEN A DARK NIGHT AND THE AIRCRAFT HAD BEEN HEAVY, THE LANDING COULD HAVE BEEN HAZARDOUS. THE REPORTER IS CONCERNED THAT THERE IS NO LONGER A READY SOURCE OF ACCURATE WIND DATA ON A PLATFORM WHICH IS A CRITICAL DESTINATION FOR FUEL. FOLLOWING A REDUCTION IN MANNING LEVELS ON THE SEAN PAPA, THE RADIO ROOM, WHERE WEATHER INFORMATION IS DISPLAYED, IS NO LONGER REGULARLY MANNED. CORRECT WIND INFORMATION IS CRITICAL FOR HELICOPTER OPERATIONS WITH THE POTENTIAL FOR A SERIOUS INCIDENT IF SUCH INFORMATION IS NOT AVAILABLE. THE MATTER WAS TAKEN UP WITH THE CLIENT, WHO IMMEDIATELY RE-INSTATED THE RADIO ROOM. AN ENQUIRY HAS BEEN INITIATED INTO HOW THESE FACILITIES COULD BE WITHDRAWN WITHOUT THE AGREEMENT OF THE CARRIER, POSSIBLY IN CONTRAVENTION OF ANO ARTICLE 34.

D.2.11 Alleged inaccurate pressure (QNH) forecasting for Shetland Basin and Sumburgh areas

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200101075**
Flight Phase :	Approach	**Occurrence Date :**	13 Feb 2001
Classification :	Occurrences	**Location :**	Shetland Basin
Events :	Miscellaneous Non-AD Occurrence	**Location Info :**	

Pretitle :

ALLEGED INACCURATE PRESSURE (QNH) FORECASTING FOR SHETLAND BASIN AND SUMBURGH AREAS.

Precis :

FORECAST QNH GIVEN AS 1008MB: ACTUAL QNH FOR EAST SHETLAND BASIN WAS 1023MB A DIFFERENCE OF 15MB OR APPROX 480FT. REPORTER STATES THAT AS THE ALTIMETER IS NOT PRESENTING USEFUL INFORMATION, THE TEMPTATION IS TO DROP IT FROM THE INSTRUMENT SCAN. ALTHOUGH A RADIO ALTIMETER IS AVAILABLE, IT OFTEN 'SPIKES' TO ZERO DURING THE TAKE OFF FROM THE INSTALLATION OR PLATFORM. IF THE A/C SHOULD SUFFER AN ENGINE FAILURE AT THIS CRITICAL STAGE, PILOT MAY NOT HAVE THE NECESSARY INFORMATION TO FLY THE PROFILE CORRECTLY OR MAY TAKE INCORRECT ACTION. SOME PILOTS ARE REFUSING TO SET VERY INACCURATE PRESSURE SETTINGS, CAUSING HEIGHT SEPARATION PROBLEMS FOR ATC. OPERATORS REVISED SYSTEM INTRODUCED TO REPLACE THE UNOFFICIAL 'BASIN RPS' WITH THE 'MARLIN RPS'. OPERATIONS BELOW A015 WILL BE ON THE CORMORANT OBSERVED PRESSURE PASSED TO A/C AS A 'COMPANY MESSAGE'. INVESTIGATION BEING PROGRESSED UNDER 2001/00956.

D.2.12 Incorrect weather passed to AS332 by oil installation

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200300164**
Flight Phase :	Landing	**Occurrence Date :**	13 Jan 2003
Classification :	Occurrences	**Location :**	Oil Installation - Harding
Events :	ATC Occurrence	**Location Info :**	

Pretitle :

INCORRECT WEATHER PASSED TO AS332 BY OIL INSTALLATION. AFTER LANDING CREW INFORMED OIL INSTALLATION PERSONNEL OF THE 'SUDDEN DETERIORATION' AND THEY REPLIED BY SAYING THEIR CLOUD/VIS MEASURING EQUIPMENT WAS U/S.

Precis :

THE OPERATOR HAS WRITTEN TO ALL CLIENTS STRESSING THE NEED FOR ACCURATE WEATHER REPORTING. A REQUEST HAS GONE TO BHAB HELIDECKS TO INCLUDE AN AUDIT OF WEATHER MEASURING EQUIPMENT WHEN CARRYING OUT HELIDECK AUDITS FOR NORTH SEA OPERATORS.

CAA Closure: NO FURTHER CAA ACTION AT THIS TIME.

D.2.13 Other

D.2.13.1 A/C crash landed in poor visibility

A/C Type :	Bell 212	**Occurrence Number :**	**198104255**
Flight Phase :	Approach	**Occurrence Date :**	09 Nov 1981
Classification :	All Other Accidents	**Location :**	ALERK ISLAND
Events :	Foreign Accident	**Location Info :**	

Pretitle :

Foreign Accident : A/C CRASH LANDED IN POOR VISIBILITY.

Precis :

AFTER WAITING 7 HOURS FOR THE WEATHER TO IMPROVE THE HELICOPTER WAS FINALLY DESPATCHED AT NIGHT IN IFR TO BE POSITIONED AT AN OIL INSTALLATION. DURING THE INSTRUMENT APPROACH TO THE OIL INSTALLATION THE CREW DESCENDED BELOW COMPANY MINIMUMS IN ICE/FOG. THE RADIO ALTIMETER WAS UNSERVICEABLE. TO SIGHT THE OIL INSTALLATION LIGHTS THROUGH THE ICE/FOG THE PILOT DESCENDED TO 150FT AGL ON HIS ALTIMETER. THE HELICOPTER STUCK THE SEA ICE AND CRASHED. TEMP CORRECTION NOT APPLIED.

D.2.14 Aircraft descended below Decision Height and landed below limits due to poor visibility/lack of fuel following two go-arounds and a diversion caused by poor weather conditions.

NB: This incident occurred at Sumburgh airfield, not an oil installation.

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200303550**
Flight Phase :	Approach	**Occurrence Date :**	07 Jun 2003
Classification :	Occurrences	**Location :**	Sumburgh (SUM)
Events :	Flight Crew Occurrence Adverse Weather Diversion / Return Contingency Low on Fuel / Out of Fuel	**Location Info :**	

Pretitle :

AIRCRAFT DESCENDED BELOW DECISION HEIGHT AND LANDED BELOW LIMITS DUE TO POOR VISIBILITY/LACK OF FUEL FOLLOWING TWO GO-AROUNDS AND A DIVERSION CAUSED BY POOR WEATHER CONDITIONS.

Precis :

THE AIRCRAFT DEPARTED FOR THE BRENT BRAVO OIL PLATFORM WITH FLORO AS DIVERSION DUE TO NON-AVAILABILITY OF SUMBURGH TAF. SUMBURGH TAF LATER BECAME AVAILABLE THEREFORE THE ALTERNATE WAS CHANGED TO SUMBURGH. BY THE TIME THE AIRCRAFT REACHED THE BRENT PLATFORM AND COMMENCED AN AIRBORNE RADAR APPROACH (ARA) THE WEATHER HAD DETERIORATED AND AT DECISION RANGE (0.75NM) AND 250FT RADAR ALTITUDE THE AIRFIELD WAS NOT VISUAL, THEREFORE A GO-AROUND WAS CARRIED OUT. THE CREW THEN ELECTED TO DIVERT TO SUMBURGH (BASED UPON THE PREVIOUS TAF AND ACTUAL WEATHER CONDITIONS) BUT WHEN THEY CHECKED WITH SUMBURGH APPROACH, THE WEATHER CONDITIONS HAD DETERIORATED THERE ALSO. BY THIS TIME THE CREW DECIDED TO CONTINUE TO SUMBURGH BUT BECAUSE THERE WERE NO VISUAL REFERENCES AT DECISION HEIGHT (250FT) ON THE FIRST APPROACH TO R/W 27 THE CREW HAD NO OTHER OPTION BUT TO GO BELOW DECISION HEIGHT ON THE SECOND APPROACH DUE TO LACK OF FUEL. THE THRESHOLD LIGHTS BECAME VISUAL AT 150FT AND AN UNEVENTFUL LANDING WAS CARRIED OUT. THE AIRCRAFT REFUELLED AND RETURNED TO ABERDEEN WITHOUT FURTHER INCIDENT.

CAA Closure: NO FURTHER CAA ACTION.

D.2.15 Loss of separation between two AS332s on instrument approaches in the same field

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200408756**
Flight Phase :	Approach	**Occurrence Date :**	25 Nov 2004
Classification :	Occurrences	**Location :**	Brent Field
Events :	Loss of Standard Separation	**Location Info :**	

Pretitle :

LOSS OF SEPARATION BETWEEN TWO AS332S ON INSTRUMENT APPROACHES IN THE SAME OIL FIELD. THE CONTROLLER'S PLAN DID NOT FULLY TAKE INTO ACCOUNT ONE OF THE AS332S PERFORMING A GO-AROUND.

Precis :

TRAFFIC INFORMATION GIVEN. WEATHER WAS POOR WITH LOW VISIBILITY. APPROPRIATE ATC FOLLOW UP ACTION HAS BEEN TAKEN.

D.2.15.1 NDB procedural approach problem in low cloud conditions

A/C Type :	Chinook	**Occurrence Number :**	**198300588**
Flight Phase :	Approach	**Occurrence Date :**	14 Mar 1983
Classification :	Occurrences	**Location :**	POLYCASTLE
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : NDB PROCEDURAL APPRCH PROBLEM IN LOW CLOUD CONDITIONS

Precis :

8/8 CLOUD AT 250FT, DESCENT TO 200FT OUT BOUND WITH 200DEG TURN TO ESTABLISH IN BOUND TRACK. DISORIENTATION PROBLEMS, NO EXTERNAL HORIZON. SUGGEST REVISED PROC WITH TURN TO BE MADE ABOVE 500FT.

CAA Closure: NDB LETDOWN IS TO BE MODIFIED TO MAKE INBOUND TURN HIGHER (800).

D.3 Approach or landed on wrong installation

D.3.1 Landed on wrong oil installation

A/C Type :	Helicopter	**Occurrence Number :**	**198903044**
Flight Phase :	Landing	**Occurrence Date :**	24 Jul 1989
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : LANDED ON WRONG OIL INSTALLATION

Precis :

CREW MISIDENTIFIED INSTALLATION FOR ONE OF IDENTICAL CONFIGURATION NEARBY IN MARGINAL WEATHER (VISIBILITY 1-1.25 MILES). MOBILE INSTALLATION HAD MOVED ALONGSIDE SUBJECT INSTALLATION OVERNIGHT GIVING SAME APPEARANCE AS INTENDED DESTINATION. NOTIFICATION OF MOVE RECEIVED 29 MINS AFTER INCIDENT.

CAA Closure: ERROR CONSIDERED DUE TO UNEXPECTED ARRIVAL OF SECOND INSTALLATION. DUE TO LARGE NUMBER OF INSTALLATIONS IN CLOSE PROXIMITY IN LEMAN & INDEFATIGABLE FIELDS COMPANIES ARE RENEWING DECK MARKINGS AND DUPLICATING WHERE POSSIBLE.

D.3.2 Landed on wrong oil installation

A/C Type :	Helicopter	**Occurrence Number :**	**199000639**
Flight Phase :	Landing	**Occurrence Date :**	08 Feb 1990
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : LANDED ON WRONG OIL INSTALLATION

Precis :

SUPERVISORY PILOT FAILED TO NOTICE CO-PILOT HAD SELECTED INCORRECT HEADING.

CAA Closure: EXISTING COMPANY FLYING STAFF INSTR PROVIDES ADEQUATE GUIDANCE ON THIS TOPIC. APPROP LOCAL ACTION TAKEN TO REMIND PILOTS OF HAZARD.

D.3.3 A/C approached & came to hover at wrong oil installation

A/C Type :	Helicopter	**Occurrence Number :**	**199001860**
Flight Phase :	Approach	**Occurrence Date :**	05 May 1990
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : A/C APPROACHED & CAME TO HOVER AT WRONG OIL INSTALLATION

Precis :

INSTALLATION COULD NOT BE POSITIVELY IDENTIFIED BY MARKINGS OR CONFIGURATION. SEE ALSO 89/03044 & 89/04882. FLT CREW NOTICE ISSUED TO REMIND CREWS OF NEED FOR POSITIVE IDENTIFICATION OF DESTINATION BEFORE MAKING COMMITMENT TO LAND.

CAA Closure: CAPT INTERVIEWED BY OPRS CHIEF PILOT. NO FURTHER ACTION PROPOSED.

D.3.4 Landed on wrong oil installation while crane as in operation

A/C Type :	Helicopter	**Occurrence Number :**	**199003412**
Flight Phase :	Landing	**Occurrence Date :**	31 Jul 1990
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : LANDED ON WRONG OIL INSTALLATION WHILE CRANE WAS IN OPERATION

Precis :

CAA Closure: PILOT MISIDENTIFIED INSTALLATION - APPROPRIATE ACTION TAKEN BY OPR. EXISTING WRITTEN INSTRS & OPERATIONAL PROCEDURES CONSIDERED ADEQUATE.

D.3.5 A/C landed on wrong oil installation

A/C Type :	Sikorsky S61	**Occurrence Number :**	**199004848**
Flight Phase :	Landing	**Occurrence Date :**	31 Oct 1990
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG OIL INSTALLATION.

Precis :

CAA CLosure: CREW MISIDENTIFIED PLATFORM HAVING BEEN DISTRACTED BY FLIGHT DECK ACTIVITIES. INVSTGN HAS SHOWN THAT ANY CHANGE TO OPERATING PROCEDURES COULD NOT HAVE PREVENTED THIS PARTICULAR OCCURRENCE. OPR HAS INITIATED ACTION TO IDENTIFY POSSIBLE HUMAN FACTOR CAUSES OF SUCH INCIDENTS.

D.3.6 A/C landed on wrong oil platform (Brent Alpha) in error

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199005661**
Flight Phase :	Landing	**Occurrence Date :**	15 Dec 1990
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG OIL PLATFORM (BRENT ALPHA) IN ERROR.

Precis :

CAA Closure: HAZARD ACCEPTABLE PROVIDED FREQUENCY OF OCC REMAINS LOW.

D.3.7 Landed on wrong oil installation

A/C Type :	SA365 Dauphin	**Occurrence Number :**	**199100567**
Flight Phase :	Landing	**Occurrence Date :**	23 Feb 1991
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : LANDED ON WRONG OIL INSTALLATION.

Precis :

CREW MISIDENTIFIED PLATFORM.

CAA Closure: CREWS REBRIEFED TO MONITOR RNAV INDICATIONS ON SHUTTLE SECTORS AND DOUBLE CHECK DECK IDENTITY BEFORE LANDING. CAA AND UK00A MONITORING SITUATION. SEE ALSO OCC 91/00625.

D.3.8 Landed on wrong off-shore platform

A/C Type :	SA365 Dauphin	**Occurrence Number :**	**199100625**
Flight Phase :	Landing	**Occurrence Date :**	02 Mar 1991
Classification :	Occurrences	**Location :**	Morecambe Bay
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : LANDED ON WRONG OFF-SHORE PLATFORM.

Precis :

CAA Closure: CREWS REBRIEFED TO MONITOR RNAV INDICATIONS ON SHUTTLE SECTORS AND DOUBLE CHECK DECK IDENTITY BEFORE LANDING. CAA AND UK00A MONITORING SITUATION. SEE ALSO OCC 91/00567.

D.3.9 Landed on wrong off-shore platform

A/C Type :	SA365 Dauphin	**Occurrence Number :**	**199103024**
Flight Phase :	Landing	**Occurrence Date :**	16 Aug 1991
Classification :	Occurrences	**Location :**	Morecambe Bay
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : LANDED ON WRONG OFF-SHORE PLATFORM.

Precis :

SEE ALSO OCC'S 91/00567 & 91/00625.

CAA Closure: NO CAA ACTION APPROPRIATE PROVIDED FREQUENCY OF OCCURRENCE REMAINS LOW.

D.3.10 Landed on wrong oil installation

A/C Type :	SA365 Dauphin	**Occurrence Number :**	**199104280**
Flight Phase :	Approach	**Occurrence Date :**	26 Sep 1991
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : LANDED ON WRONG OIL INSTALLATION.

Precis :

PILOT FAILED TO COPY FULL ROUTEING ONTO FLT LOG UNTIL AFTER T/O. HE THEN MISTAKENLY SUBSTITUTED AV, FOR API AS THE FIRST STOP.

D.3.11 A/C landed on wrong oil platform (Eider) in error

A/C Type :	Bell 212	**Occurrence Number :**	**199201481**
Flight Phase :	Approach	**Occurrence Date :**	23 Apr 1992
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG OIL PLATFORM (EIDER) IN ERROR.

Precis :

CAA Closure: HAZARD ACCEPTABLE PROVIDED FREQUENCY REMAINS LOW.

D.3.12 Landed on wrong oil installation

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199301764**
Flight Phase :	Approach	**Occurrence Date :**	15 May 1993
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : LANDED ON WRONG OIL INSTALLATION.

Precis :

OPERATING PROCEDURES REVIEWED BY OPERATOR TO ENSURE POSITIVE IDENTIFICATION OF INSTALLATION IS MADE BEFORE LANDING.

CAA Closure: HAZARD ADEQUATELY CONTROLLED BY OPERATOR'S ACTION.

D.3.13 Misidentified oil installation in poor weather conditions. Go round initiated.

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199403836**
Flight Phase :	Approach	**Occurrence Date :**	24 Aug 1994
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : MISIDENTIFIED OIL INSTALLATION IN POOR WEATHER CONDITIONS. GO ROUND INITIATED.

Precis :

SUBSEQUENTLY LANDED ON CORRECT INSTALLATION. NDB NOT USABLE DUE CONGESTION IN AREA. OPRS CHECKLISTS AMENDED TO INCLUDE A POSITIVE IDENTIFICATION DURING APPROACH.

CAA Closure: HAZARD ACCEPTABLE PROVIDED FREQUENCY OF OCCURRENCE REMAINS LOW.

D.3.14 A/C landed on wrong installation following destination change.

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199404358**
Flight Phase :	Approach	**Occurrence Date :**	28 Sep 1994
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG INSTALLATION FOLLOWING DESTINATION CHANGE.

Precis :

ON SECOND FLIGHT OF DAY DURING ROTORS RUNNING TURNROUND, CO-PILOT COLLECTED INFO ON DESTINATION CHANGE. POSITION OF NEAREST FIXED PLATFORM ENTERED INTO RNAV FOR LANDING ON ONE OF THE TWO ADJACENT INSTALLATIONS. WHILST ATTENTION BEING PAID TO CONTROLLING A/C IN 30KT WIND IN TURBULENT SECTOR, INSTALLATION WAS NOT VISUALLY IDENTIFIED. A/C INADVERTENTLY LANDED ON SEDCO 714 ADJ TO PLATFORM & NOT SEDCO 704 APPROX 2 MILE TO WEST. UNAPPROVED SOURCE OF NAV DATA USED, WHICH SHOWED BOTH INSTALLATIONS ADJACENT TO PLATFORM. SEE DIGEST 94/D/22.

CAA Closure: HAZARD ADEQUATELY CONTROLLED BY EXISTING PROCEDURES.

D.3.15 Landed on wrong oil installation

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199505165**
Flight Phase :	Landing	**Occurrence Date :**	28 Nov 1995
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : LANDED ON WRONG OIL INSTALLATION.

Precis :

CAA Closure: APPROPRIATE COMPANY ACTION TAKEN.

D.3.16 A/C landed on wrong offshore platform

A/C Type :	Sikorsky S76	**Occurrence Number :**	**199605438**
Flight Phase :	Landing	**Occurrence Date :**	25 Nov 1996
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG OFFSHORE PLATFORM.

Precis :

TWO SHUTTLE FLIGHTS WERE REQUIRED TO FERRY ALL PERSONNEL FROM A MANNED PLATFORM TO A SMALL UNMANNED SATELLITE PLATFORM. FIRST RETURN TRIP PROCEEDED NORMALLY BUT DURING SECOND FLIGHT A/C ENTERED A HEAVY RAIN SHOWER, RESULTING IN REDUCED VISIBILITY & INCREASED COCKPIT WORKLOAD. AFTER LANDING THE SHOWER CEASED & CREW REALISED THEY HAD LANDED ON A SISTER SATELLITE PLATFORM APPROX 1.5 MILES FROM INTENDED DESTINATION. REPORTER NOTES THAT DECK MARKINGS ON BOTH PLATFORMS ARE PARTIALLY OBSCURED BY BIRD DROPPINGS. APPROPRIATE COMPANY ACTION TAKEN.

D.3.17 A/C landed on wrong installation following destination change

A/C Type :	Sikorsky S76	**Occurrence Number :**	**199700220**
Flight Phase :	Landing	**Occurrence Date :**	17 Jan 1997
Classification :	Occurrences	**Location :**	OIL INSTALLATION
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG INSTALLATION FOLLOWING DESTINATION CHANGE.

Precis :

ON SHUTDOWN ON CLIPPER PLATFORM PILOT ADVISED OF ROUTE CHANGE TO BARQUE PL. THERE ARE TWO PLATFORMS - BARQUE PB & BARQUE PL. BARQUE PL IS KNOWN TO PILOTS AS BARQUE EXTENSION OR SPLI BUT NEW R/T OPERATOR WAS UNAWARE OF THIS & CALLED IT BY ITS CORRECT DESIGNATION. PILOTS THEREFORE ASSUMED PICK UP WAS FROM BARQUE PB SO ROUTED ACCORDINGLY FLYING PAST BARQUE PL (SPLI) CALLING FOR & RECEIVING CLEARANCE FOR BARQUE PB. APPROPRIATE ACTION TAKEN BY OPR.

CAA Closure: HAZARD ACCEPTABLE PROVIDED FREQUENCY OF OCCURRENCE REMAINS LOW.

D.3.18 A/C landed on wrong offshore platform. Installation misidentified. A/C repositioned to correct platform

A/C Type :	Sikorsky S61	**Occurrence Number :**	**199706751**
Flight Phase :	Landing	**Occurrence Date :**	18 Dec 1997
Classification :	Occurrences	**Location :**	BRENT B
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : A/C LANDED ON WRONG OFFSHORE PLATFORM. INSTALLATION MISIDENTIFIED. A/C REPOSITIONED TO CORRECT PLATFORM.

Precis :

SEE ALSO 97/06137. APPROPRIATE PERSONNEL ACTION TAKEN, FLIGHT SAFETY INSTRUCTION ISSUED & COMPANY PROCEDURES REVIEWED.

CAA Closure: HAZARD ADEQUATELY CONTROLLED BY REPORTER'S ACTION.

D.3.19 A/C landed on wrong oil installation

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200102805**
Flight Phase :	Landing	**Occurrence Date :**	01 May 2001
Classification :	Occurrences	**Location :**	North Sea
Events :	Landed at Wrong Place	**Location Info :**	

Pretitle :

AIRCRAFT LANDED ON WRONG OIL INSTALLATION.

Precis :

OPERATOR INVESTIGATION REVEALED THE AIRCREW HAD ERRONEOUSLY IDENTIFIED THE TWO RADAR RETURNS AS THE PIPER AND A SUPPLY BOAT WHEN IN FACT THEY WERE THE PIPER AND THE TARTAN. HOWEVER, WHAT THEY SUBSEQUENTLY SAW VISUALLY WAS THE TARTAN INSTALLATION AND THE SUPPLY BOAT. THERE WERE OTHER CONTRIBUTORY FACTORS IDENTIFIED INCLUDING THE ISSUE OF THE VISIBILITY OF THE TARTAN INSTALLATION NAMEPLATE, PARTICULARLY IN POOR VISUAL CONDITIONS. THE IMPORTANCE OF NOT CONTINUING THE APPROACH TO LAND WITHOUT POSITIVELY IDENTIFYING THE INSTALLATION WAS REITERATED TO THE CREW AND HIGHLIGHTED ONCE AGAIN TO ALL OTHER CREWS IN THE COMPANY. OPERATORS ARE REVIEWING AGAIN THE WAYS OF DEVISING A VISUAL MEANS OF INDICATING TO PILOTS (SUCH AS A FLASHING GREEN LIGHT ON THE DECK) THAT THE DECK IS CLEAR FOR HELICOPTER OPERATIONS.

CAA Closure: THE HAZARD IS CONTROLLED BY THE ACTIONS STATED ABOVE.

D.3.20 A/C landed on wrong helideck due to an error in programming the RNAV

A/C Type :	SA365 Dauphin	**Occurrence Number :**	**200104869**
Flight Phase :	Landing	**Occurrence Date :**	15 Jul 2001
Classification :	Occurrences	**Location :**	Oil Installation
Events :	Landed at Wrong Place	**Location Info :**	

Pretitle :

AIRCRAFT LANDED ON WRONG HELIDECK DUE TO AN ERROR IN PROGRAMMING THE RNAV.

Precis :

SEE ALSO 2001/02805.

D.3.21 A/C landed on wrong offshore platform. Installation misidentified. A/C repositioned to correct platform

A/C Type :	Sikorsky S76	**Occurrence Number :**	**200008213**
Flight Phase :	Landing	**Occurrence Date :**	24 Oct 2000
Classification :	Occurrences	**Location :**	Oil Installation
Events :	Flight Crew Occurrence	**Location Info :**	

Pretitle :

A/C LANDED ON WRONG OFFSHORE PLATFORM. INSTALLATION MISIDENTIFIED. A/C REPOSITIONED TO CORRECT PLATFORM.

Precis :

THE OPERATOR ADVISED THAT THE CORRECT PROCEDURES, BRIEFINGS AND SETTING OF AIRCRAFT NAVIGATION SYSTEMS HAD BEEN COMPLETED FOR A LANDING ON THE INTENDED INSTALLATION. THE P1S NORMAL PROCEDURE WHEN LANDING OFFSHORE IS TO STATE AND CONFIRM THE DECK HE IS LANDING ON PRIOR TO COMMITTAL. HE DOES NOT KNOW WHY THIS DID NOT HAPPEN ON THIS OCCASION.

CAA Closure: WHILST THE ADDITIONAL PROCEDURE CARRIED OUT ON THE SOUTHERN NORTH SEA INSTALLATIONS OF CALLING FINALS AND RECEIVING CONFIRMATION FROM THE HLO THAT THE AIRCRAFT IS IN SIGHT FAILED TO PREVENT THIS OCCURRENCE, THE TWO PILOTS WERE WELL AWARE, PARTICULARLY FOLLOWING THIS EVENT, OF THEIR ERRORS. THE OPERATOR'S OTHER PILOTS WILL BE MADE FULLY AWARE OF THIS INCIDENT.

D.3.22 Incorrect deck landing

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200408340**
Flight Phase :	Landing	**Occurrence Date :**	17 Nov 2004
Classification :	Occurrences	**Location :**	North Sea
Events :	Landed at Wrong PlaceNavigation ErrorPoor Visibility	**Location Info :**	

Pretitle :

INCORRECT DECK LANDING.

Precis :

AS THE AIRCRAFT APPROACHED THE OIL FIELD COMPLEX, ATC ADVISED THAT A HEAVY SQUALL WAS ABOUT TO ENVELOP THE DESTINATION PLATFORM ALTHOUGH OTHER INSTALLATIONS IN THE VICINITY WERE STILL VISUAL. TURBULENCE WAS MARKED, CONSEQUENTLY THE AIRCRAFT ALTERED TRACK BEFORE IDENTIFYING A PLATFORM ON THE CORRECT BEARING. DECK CLEARANCE AND PRE-LANDING CHECKS WERE COMPLETED PRIOR TO A SAFE LANDING. WHEN THE PILOT ALIGHTED FROM THE AIRCRAFT IT WAS FOUND THE LANDING HAD TAKEN PLACE ON AN INCORRECT INSTALLATION. NO ONE WAS SEEN ON THE INSTALLATION. THE HELICOPTER THEN TOOK OFF AND LANDED AT THE CORRECT DESTINATION. SUBSEQUENT INVESTIGATION SUGGESTED SPATIAL DISORIENTATION AS A CAUSAL FACTOR. IN INTERMITTENTLY POOR VISIBILITY IN MODERATE TURBULENCE, A PLATFORM BECAME VISUAL THROUGH THE LIMITED VISIBILITY WHERE THE CREW EXPECTED TO SEE IT AND THEIR MINDSET WAS THAT IT WAS THEIR DESTINATION. THERE WAS NO ACTIVITY ON THE PLATFORM AS THEIR CREW WAS AT LUNCH, THUS IT WAS CONCLUDED THERE WAS NO HAZARD TO THE SAFETY OF THE AIRCRAFT OR PLATFORM.

D.4 System related

D.4.1 NDB or ADF

D.4.1.1 NDB on oil installation switched off in error

A/C Type :	Sikorsky S61	**Occurrence Number :**	**198100868**
Flight Phase :	Approach	**Occurrence Date :**	26 Mar 1981
Classification :	Occurrences	**Location :**	PIPER ALPHA
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : NDB ON OILINSTALLATION SWITCHED OFF IN ERROR

Precis :

RAD OP INFORMED THAT A/C TO CARRY OUT BEACON LETDOWN ON ARRIVAL.BEACON SWITCHED ON. PILOT CALLED 'BEACONS OUTBOUND'-BEACON SWITCHED OFF. LETTER SENT TO OIL COMPANY RE RAD OP TRAINING.

D.4.1.2 NDB "KUK" interference by NDB "OVT" "OVT" NDB not switched off by installation ATC

A/C Type :	Bell 214	**Occurrence Number :**	**198601246**
Flight Phase :	Approach	**Occurrence Date :**	24 Apr 1986
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : NDB 'KUK' INTERFERENCE BY NDB 'OVT' 'OVT' NDB NOT SWITCHED OFF BY INSTALLATION ATC

Precis :

NO A/C WORKING 'OVT' SO NDB SHOULD HAVE BEEN SWITCHED OFF.ATTEMPTED 'OFF' REQUESTS ON A/C FREQ FAILED SO INSTALLATION CALLED ON MARINE FREQ.A/C UNABLE TO APPROACH 'KUK' UNTIL INTERFERENCE REMOVED AS WX ON MINIMA. (KUK-KINGSNORTH INSTALLATION, OVT-OCEAN VICTORY).

CAA Closure: CONSIDERED TO BE RANDOM OCCURRENCE.CURRENT PROCEDURES FOR OFF- SHORE NDB OPERATION CONTAIN ADEQUATE PROVISION FOR SUCH SITUATIONS & ARE WELL UNDERSTOOD BY INSTALLATION OPERATORS. MATTER TAKEN UP WITH OPERATING COMPANY WHO HAVE AMENDED THEIR INSTRS TO RADIO OPERATORS IN ORDER TO REDUCE LIKELIHOOD OF ANY FURTHER INCIDENT.

D.4.1.3 NDB needle flicking between different beacons with overlapping idents at 2nm range, indications normal at 10nm & 6nm

A/C Type :	Sikorsky S61	**Occurrence Number :**	**199303300**
Flight Phase :	Approach	**Occurrence Date :**	20 Sep 1993
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : NDB NEEDLE FLICKING BETWEEN DIFFERENT BEACONS WITH OVERLAPPING IDENTS AT 2NM RANGE, INDICATIONS NORMAL AT 10NM & 6NM.

Precis :

OCCURRED AS A RESULT OF THREE A/C SIMULTANEOUSLY, ON REQUEST, USING THREE DIFFERENT NDB'S ON A SINGLE FREQUENCY 553.5KHZ.

CAA Closure: ALL OIL INSTALLATION NDB OPERATORS REMINDED TO ENSURE THAT THEIR NDB FREQUENCY IS VACANT PRIOR TO SWITCHING NDB ON. UK AIR PILOT ALSO AMENDED.

D.4.1.4 NDB ident did not match selected frequency and QDM

A/C Type :	Sikorsky S61	**Occurrence Number :**	**199400095**
Flight Phase :	Approach	**Occurrence Date :**	13 Jan 1994
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : NDB IDENT DID NOT MATCH SELECTED FREQUENCY AND QDM.

Precis :

FREQUENCY SELECTED WAS 397 BUT IDENT WAS "KM" WITH QDM OF 135DEG.

CAA Closure: SOURCE IDENTIFIED IN HOLLAND & STOPPED BY DUTCH AUTHORITIES. A POSSIBLE ALTERNATIVE SOURCE OF INTERFERENCE IS NDB HELGOLAND "DHE" ON 397.2 KHZ WHICH MIGHT BECOME DOMINANT IF OIL INSTALLATION NDBS ON 397 KHZ LOSE POWER.

D.4.1.5 NDB ident did not match selected frequency & indications erratic

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199404134**
Flight Phase :	Approach	**Occurrence Date :**	15 Jun 1994
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :

Other Occurrence : NDB IDENT DID NOT MATCH SELECTED FREQUENCY & INDICATIONS ERRATIC.

Precis :

KIRKWALL (KW) IDENT ON 395KHZ CLEARLY AUDIBLE WHEN CLAYMORE (CE) ON 397KHZ SELECTED. SEE DIGEST 94/D/21.

CAA Closure: CLAYMORE NDB FREQ CHANGED TO 428.5 WEF 31 AUG 95.

D.4.1.6 Erroneous RNAV & ADF indications

A/C Type :	Sikorsky S61	**Occurrence Number :**	**199601475**
Flight Phase :	Approach	**Occurrence Date :**	24 Apr 1996
Classification :	Occurrences	**Location :**	NORTH SEA
Events :	Other Occurrence	**Location Info :**	

Pretitle :
Other Occurrence : ERRONEOUS RNAV & ADF INDICATIONS.

Precis :
ON APPROACH RNAV APPEARED TO SHOW INCORRECT POSITION. CREW REQUESTED APPROPRIATE NDB & OBSERVED THAT ADF CONTINUALLY SHOWED INSTALLATION IN 12 'O' CLOCK POSITION EVEN AFTER A/C HAD PASSED INSTALLATION.

D.4.2 WX Radar

D.4.2.1 Radar failed 3NM from installation NR1 ESS BUS C B Tripped

A/C Type :	Bell 212	**Occurrence Number :**	**198400323**
Flight Phase :	Approach	**Occurrence Date :**	07 Feb 1984
Classification :	Occurrences	**Location :**	
Events :	Occurrence	**Location Info :**	

Pretitle :
Occurrence : RADAR FAILED 3 NM FROM INSTALLATION NR1 ESS BUS C B TRIPPED

Precis :
INVESTIGATION OF NR1 ESS BUS IN HAND.

CAA Closure: EXHAUSTIVE TESTS FAILED TO REVEAL CAUSE. NO PROBLEMS REPORTED SINCE. CONSIDERED RANDOM FAULT.

D.4.3 Displays

D.4.3.1 Loss of all 4 display screens & IFDS failure

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**199905951**
Flight Phase :	Approach	**Occurrence Date :**	31 Aug 1999
Classification :	Occurrences	**Location :**	North Sea
Events :	Other Occurrence	**Location Info :**	

Pretitle :

LOSS OF ALL 4 DISPLAY SCREENS & IFDS FAILURE.

Precis :

DURING FINAL PHASE OF FULLY COUPLED RADAR APPROACH TO INSTALLATION, THE 'TAKE MANUAL CONTROL' CAPTION FLASHED BRIEFLY THEN ALL 4 DISPLAY SCREENS WENT BLANK FOR 2 SECONDS BEFORE RECOVERING. THE FLASHING 'TAKE MANUAL CONTROL' CAPTION WAS STILL DISPLAYED & THE NR1 AFCS 'DIS' WARNING WAS SHOWING. THE AFCS WAS SELECTED 'OUT' & 'IN' ON THE CYCLIC & THE APPROACH COMPLETED MANUALLY WITHOUT FURTHER INCIDENT. THE AIRCRAFT MANUFACTURER AND OEM WERE UNABLE TO IDENTIFY ANY FAULTS.

CAA Closure: THE HAZARD IS ACCEPTABLE PROVIDED THE FREQUENCY REMAINS LOW.

D.4.4 Altimeter

D.4.4.1 Multi radio altimeter malfunction

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**198503063**
Flight Phase :	Approach	**Occurrence Date :**	30 Aug 1985
Classification :	Occurrences	**Location :**	North Sea
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : MULTI RADIO ALTIMETER MALFUNCTION

Precis :

BOTH ALTIMETERS STUCK AT 370F TX/RX.

CAA Closure: RAD ALT CHECKED BUT NO FAULT FOUND.ADD RAISED TO CHANGE TX-RX WHEN SPARES AVAILABLE.AFTER CHANGE NO FURTHER PROBLEM REPORTED. CONSIDERED TO BE RANDOM OCC, HOWEVER, COMPANY ADVISED AGAINST PERMITTING SUSPECT TX-RX TO REMAIN IN SERVICE AS ADD IN VIEW OF MAND REQUIREMENT FOR RAD ALT. NO FURTHER CAA ACTION.

D.4.4.2 Multi radio altimeter malfunction both gauges stopped at 200ft

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**198504237**
Flight Phase :	Landing	**Occurrence Date :**	03 Dec 1985
Classification :	Occurrences	**Location :**	North Sea
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : MULTI RADIO ALTIMETER MALFUNCTION BOTH GAUGES STOPPED AT 200FT

Precis :

GAUGES DESCENDED NORMALLY TO 200FT THEN STOPPED WITH SLIGHT OSCILLATION. A 'PRESS TO TEST' SELECTION CLEARED THE PROBLEM. SEE ALSO 85/04246 & 04561.

CAA Closure: THIS PROBLEM IS APPARENTLY DUE TO RAD ALT REMAINING LOCKED ON TO SEA HEIGHT AFTER CROSSING DECK EDGE OF OIL INSTALLATION. RAD ALT ANTENNA CONTINUES TO RECEIVE SIGNAL RETURNS FROM SEA AT THIS STAGE & ONLY REMEDY SEEMS TO BE A PRESS TO TEST WHICH RESETS ALT TO DECK HT. OPR TO BE ADVISED OF EXPLANATION & REMEDY, ALTHOUGH SITUATION IS NOT CONSIDERED TO BE HAZARDOUS. ADDIT INFO:FALSE INDICN DUE TO POSN OF RAD ALT ANTENNAE UNDERTAIL BOOM WHICH OFTEN EXTENDS BEYOND HELIDECK. EQUIP NOT AT FAULT & SPECIAL CIRCUMSTANCES PRECLUDE FALSE READING IN OTHER FLIGHT PHASES.

D.4.4.3 Multi radio altimeter malfunction both gauges stopped at approx 180 ft

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**198504246**
Flight Phase :	Landing	**Occurrence Date :**	04 Dec 1985
Classification :	Occurrences	**Location :**	FORTIES B
Events :	Occurrence	**Location Info :**	

Pretitle :

Occurrence : MULTI RADIO ALTIMETER MALFUNCTION BOTH GAUGES STOPPED AT APPROX 180 FT

Precis :

GAUGES DESCENDED NORMALLY TO APPROX 180FT THEN STOPPED BUT VARIED SLOWLY BETWEEN 170 & 190FT. A 'PRESS TO TEST' SELECTION CLEARED THE PROBLEM. TX/RX REPLACED. TX/RX EQUIP REMOVED FROM G-BKZG AFTER PREVIOUS MALFUNCTION. SEE ALSO 85/04237 6 85/04561.

CAA Closure: SEE 85/04237 FOR INVESTIGTN & CLOSURE STATEMENT.

D.4.4.4 Radio altimeter stuck at 300ft during approach in good weather. Aircraft landed safely.

A/C Type :	SA332 Super Puma	**Occurrence Number :**	**200101416**
Flight Phase :	Approach	**Occurrence Date :**	01 Mar 2001
Classification :	Occurrences	**Location :**	North Sea
Events :	A/c Equipment / System Malfunction	**Location Info :**	

Pretitle :

RADIO ALTIMETER STUCK AT 300FT DURING APPROACH IN GOOD WEATHER. AIRCRAFT LANDED SAFELY.

Precis :

ON DECK THE TEST BUTTON WAS PRESSED AND THE INDICATOR NEEDLE MOVED TO ZERO FEET, WHICH WAS THE CORRECT READING. RADIO ALTIMETER PERFORMANCE MONITORED FOR REST OF DAY AND NO FURTHER FAULTS NOTED.

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Part 2, Annex E Information from RDR-1400 Manufacturer

E.1 Introduction

E.1.1 This annex gives information received from Telephonics, the manufacturer of the RDR-1400 weather radar system. The responses received were in answer to questions posed to help determine the reliability and integrity of the RDR-1400 weather radar.

E.2 Answers to questions

E.2.1 The following list presents the questions asked and associated responses.

- What standards is this product certified to?
  - The RDR-1400 radar is certified by the FAA to meet TSOs C63b [3] and C102 [6] certification. The TSOs respectively require that the radar meets or exceeds the requirements of RTCA DO-173 [2] for a Weather radar and RTCA DO-172 [1] for a maritime Search and Rescue and Beacon radar.
- What are the standard maintenance procedures?
  - In accordance with the TSO, an Installation and Maintenance manual is required. The radar is maintained and repaired in accordance with these manuals. All components are repaired upon fault indication or pilot malfunction report.
- Is there a measurement of the rate of false returns provided by the radar, i.e. no return when there is a target or a return when there is no target?
  - All radars are characterised by a false alarm rate (a return when there is no target) and a probability of detection (no return when there is a target). The false alarm rate of the RDR-1400 in the is 5 indications per 120 degree scan; note that this is equivalent to about 1 indication per 1 million possible indications again this is very low. As far as detection is concerned, there is a minimum target size or weather cell that is detectable, which is different as a function of range. In the weather mode the radar can reliably detect and report the level via colours of 4 to 50 millimetres of rain out to 50 nautical miles. Beyond 50 nautical miles only increasing amounts of rain can be seen. This is in accordance with the TSO certified requirements.

    In the search mode the operator can control the detection levels via a gain control. The size of the detectable target will increase as the target range from the radar increases and as the operator sets the radar gain and signal processing control modes. The operator varies the modes and levels to optimise the target detection with respect to the radar signals coming from the water and wave levels.
- Is there a measurement of the maximum error (system undetected in both range and azimuth) that the radar may present to the flight crew?
  - No, however operator experience and training usually allows the operator to recognize potential false detection and real detection situations. Generally, target persistence or lack of persistence is used to determine the viability of a target indication.

- Are there any ratings for this weather radar in terms of continuity, availability, accuracy and integrity?
  - The TSO and DO-173 requirement rate the RDR-1700C as a class CL7 weather radar meaning that it has the ability to detect weather out to 240 nautical miles.
  - Accuracy with respect to range and azimuth meet and exceed the +/- 2% requirement of RTCA DO-172 and DO-173.
  - The radar also has a Mean Time between Failure Rating of 1600 Hrs meaning that the radar in normal operation can be expected to require repair once every 1600 hours or operation.
  - The RDR-1400 has been analysed to have a probability of generating misleading data of 2.18×10^{-6}.

Part 2, Annex F Weather Radar Maintenance and Test Requirements

F.1 General

F.1.1 This Annex provides a summary of the maintenance and test requirements as specified in the regulatory material to which the radar are certified.

F.2 Certification standards

F.2.1 As noted from Telephonics, the RDR-1400 weather radar system is certified to comply with the requirements of TSO-C63b [3] and TSO-C102 [6] certification. In addition, the Honeywell Primus 700 radar system is certified to TSO-C63c [4] and TSO-C102 [6].

F.2.2 These technical standing orders specify the FAA requirements for the use of weather radar systems. In addition, the FAA have defined maintenance requirements in AC 90-80B [7]. This states that compliance with any of the procedures is achieved through either TSO-C102 or TSO-C63.

F.2.3 Together these three documents form the basis for the certification of the weather radar system. All of these certification standards either require compliance with RTCA DO-172 [1] and DO-173 [2] respectively, or state that compliance with these two industry standards will meet the regulatory requirements.

F.3 Maintenance requirement

F.3.1 The regulatory standards therefore require maintenance in accordance with DO-172 and DO-173. Helios has compared the maintenance requirements detailed in the RDR-1400 maintenance manual with the requirements for DO-172 and DO-173 and noted a close similarity between the industry standards and the radar manufacturers maintenance requirements.

F.3.2 The testing and maintenance specified within the standards consists of conformity inspection, ground testing and flight testing.

F.3.3 Conformity inspection is conducted to:

> "Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. Verify that all mechanical and electrical connections have been properly assembled and that the equipment has been installed and located according to the manufacturer's recommendations"

F.3.4 Ground testing and flight testing are detailed for use with installed equipment. The general ground test procedures cover:

- Equipment function.
- Interference effects.
- Bearing alignment tests.
- Power supply fluctuation.
- Equipment accessibility.

F.3.5 The flight test procedures cover:

- Display visibility.
- Interference effects.
- Range performance.[1]
- Stabilisation performance.
- Navigation performance - requires evaluation of aircraft track over the ground while flown in VFR conditions, and includes at least one non-precision approach for each radar operating mode.

F.3.6 In addition to the installed equipment tests, test procedures are also defined which the manufacturer must test the equipment against in order to achieve compliance with the standard. If it is assumed that the maintenance procedures follow these original installation equipment test procedures, then the tests covered include the following in some detail:

- Operation of controls.
- Indicator readability.
- Beacon identification processor.
- Area scan and display.
- Receiver gain control.
- Antenna beam characteristics.
- Beam tilting.
- Antenna stabilisation.
- Target update rate.
- Sensitivity time control.
- Performance index factor.
- Bearing accuracy.
- Indicated range accuracy.
- Minimum range.
- Frequency control.
- Receiver selectivity - primary radar mode.
- Receiver selectivity - beacon mode.
- Radio frequency emission.
- Pulse width measurement.
- Beacon fixed delay.

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[1] It is noted that the ARA procedure is approved through the use of AC 90-80B. This document states that any ARA system used for ARA shall meet the requirements of TSO-C63 or TSO-C102. TSO-C63 requires compliance with DO-173. TSO-C102 requires compliance with DO-172. AC 90-80B has indicated range error requirements of ± 0.2NM for displays of 5NM or less. Meanwhile DO-173 requires that the error "shall not exceed 10% of the actual target distance, or one nm, whichever is greater". DO-172 then states, "… shall not be greater than ±600 feet (2s) for distances of 5 nm or less for Phase I and ±300 feet (2s) for Phase II and shall not be greater than 5% of the indicated range for display ranges greater than 5 nm …".

F.4 Pre-flight requirements

F.4.1 In addition to the general maintenance requirements, DO-172 places requirements on the normal checks that must be completed prior to initiation of a flight in which ARA equipment is expected to be used. These are:

- Power input.
- Antenna tilt and stabilisation.
- ARA display range scales.
- Equipment operating modes.

F.4.2 The way in which these tests are to be conducted is also explained in DO-172.

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Part 2, Annex G RDR-1400 Operations and Maintenance

G.1 General

G.1.1 This annex presents information gathered following a site visit to Turner Aviation's Aberdeen repair facility. A questionnaire was prepared prior to the visit.

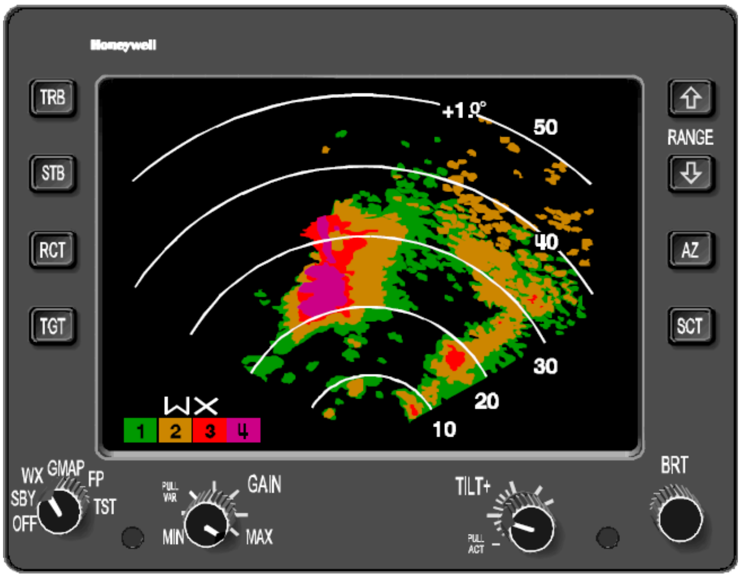
G.2 Component installation

G.2.1 The following components are detailed as part of the weather radar installation:

- Radar antenna.
- Receiver-Transmitter.
- Radar indicator.
- Interface unit (where multiple indicators are installed).
- Waveguide and associated cables.
- Remote range control switch.

G.2.2 Each of these components is subjected to the visual inspection check.

G.2.3 The following diagram illustrates the interface to the RDR-1400.



G.3 Inbuilt system checks

G.3.1 The RDR performs a self check when first switched on. The check verifies that:

- The radar is correctly transmitting;
- The radar is correctly receiving.

G.3.2 These internal checks essentially verify that the transmit and receive circuit timings are within tolerance of one another.

G.3.3 In addition to these checks, additional test patterns are displayed to determine whether the display unit is functioning correctly. The four checks undertaken by visual inspection of the display are:

- Check the test pattern.
- Check and adjust antenna stabilisation.
- Check weather alert mode.
- Check target alert mode.

G.3.4 Transmit, receive and display functionality are tested by the flight crew following power on, with the test beginning when the flight crew select the test position on the switch, as indicated in the previous diagram.

G.3.5 During operation the system constantly monitors itself for transmit and receive errors. Detected errors are indicated to the flight crew on the weather radar display with transmission faults indicated with a "RT Fault" alert and antenna faults indicated with an "ANT Fail" alert.

G.3.6 The firing of the weather radar pulse is controlled through a magnetron. If the magnetron fails, the fault will exhibit itself through a gradual loss of sensitivity. This will only be detected once the system falls out of tolerance and the automatic frequency control fails resulting in a "RT Fault".

G.4 Operational faults

G.4.1 A number of faults have been recorded by the repair facility. The frequency with which individual radars fail is not known. The following faults are examples of failures that have been reported to the repair facility:

- The range button becomes sticky and fails to operate.
- The weather radar display fails.
- High voltage failure (11kV required to drive the display tube).
- The weather radar fails to show returns when installed.
- Loss of returns (e.g. the receiver going to wait and restarting after a few seconds).
- Seized antenna motors.

G.4.2 In addition to obvious failures such as these, non-faults have also been reported by flight crews. For example, the weather radar has been known to pick up reflected voice VHF communications between flight crew and air traffic or flight crew and the installation in bad weather. This can clog the screen with returns which the flight crew think is a fault.

G.5 Operational modes

G.5.1 The main modes that the weather radars operate in are map and weather modes. Information from a radar maintenance facility indicates that, for the RDR-1400, the differences between weather mode and map mode are as follows:

- In weather mode the receiver gain is fixed and calibrated and there are no processing adjustments available to the operator (so as to accurately indicate precipitation levels). In the weather mode the display colours are green, yellow and red.
- In Mapping mode the operator can select the gain, change contours and apply clutter suppression if desired. In the mapping mode the colours are blue, yellow and red.

G.5.2 The radar waveform (i.e. the pulse width and pulse repetition frequency) are the same.

G.5.3 New model weather radars such as the Honeywell Primus 700 operate on a variable pulse width depending on the range and mode. The pulse width varying from 0.1 to 3.5ms.

G.5.4 Different weather radars are believed to treat weather and mapping modes differently.

G.6 Minimum display ranges

G.6.1 The minimum display ranges available to the flight crew vary between weather radars. They also vary according to the pulse width of the radar. The minimum displayed range could be several miles depending on the range setting.

G.6.2 The popular RDR-1400 has a minimum range of 0.5NM. The Honeywell Primus 500 by contrast has a minimum range of 2.5NM.

G.6.3 The RDR-1400 and the modern Honeywell Primus 700 have the following range scale: 0.5, 1, 2.5, 5, 10, 25, 50, 100, 200, 300 NM.

G.7 Gyroscopic stabilising

G.7.1 The RDR-1400 has the option to have a gyroscope input to give both pitch and roll stabilisation. The gyroscope is not part of the radar, but the input is provided through a feed to radar antenna from the aircraft gyroscope. The gyroscope has no affect on the operation of the weather radar, only ensuring that the weather radar maintains the tilt when the aircraft pitch angle is high, e.g. resulting from a rapid speed reduction. It is not known whether the radar is, as standard, connected to the gyroscope.

G.7.2 Any loss of stabilisation should be immediately obvious to the flight crew from a result of increase control inputs required.

G.7.3 A loss of the gyroscope input to the weather radar would generally be noticed by the flight crew from a change in the image presented on the weather radar. Malfunctions of the gyroscope feed could be caused through loose connections or water shorting contacts.

G.7.4 The RDR-1400 also features tilt control.

G.8 Azimuth errors

G.8.1 Errors that may not be detected by the flight crew result from azimuth failures. For, example:

- There is no indication given to the flight crew what the radar tilt is.
- A short on a gyroscope connection may result in the radar looking at a different azimuth than that selected by the flight crew.

G.8.2 However, it is expected that in most instances the flight crew would recognise that the error existed.

G.9 Antenna mounting

G.9.1 The antenna mounting is a solid cast mount attached to the fuselage of the aircraft by four bolts. All four retaining bolts would have to loosen for the mounting to shift. With such a solid mounting the chances of this breaking loose during flight are deemed to be extremely remote.

G.9.2 Instructions for mounting the antenna are detailed in the maintenance manual, including mounting templates.

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Part 2, Annex H Radio Altimeter Check Procedures

H.1 General

H.1.1 This Annex presents the test procedures for the Honeywell AA-300 radio altimeter.

H.1.2 The checks for the radio altimeter relate to post installation checks, pre-flight tests and inflight tests. The tests for each are detailed as follows.

H.2 Post installation checks.

H.2.1 The following steps should be conducted to complete the post installation checks:

- Apply system power.
- Make sure indicator warning (OFF) flag clears and that the display pointer moves to a position near zero feet.
- Operate the radio altimeter for a minimum of 15 minutes (warm-up period) and then adjust for zero height.
- Complete the pre-flight test procedures.
- Following successful pre-flight tests perform an inflight test.

H.3 Pre-flight tests

H.3.1 The following steps should be conducted to complete the pre-flight installation checks:

- Rotate DH Set knob on indicator to set bug to 50 feet.
- Apply system power. The red warning (OFF) flag on the indicator shall clear and the indicator pointer should indicate 0+/-5ft.
- Push and hold the TEST button on the indicator. The display pointer should indicate 100 +/- 10ft, the DH annunciator must be OFF, the warning (OFF) flag must be in-view.
- Release the TEST button. The display pointer must return to 0 +/- 5ft, the DH annunciator shall illuminate, and the warning (OFF) flag shall clear.

H.4 Inflight tests

H.4.1 The following steps should be conducted to complete the inflight installation checks:

- Make sure the warning (OFF) flag is out-of-view when system power is applied.
- Make sure the indicator pointer is out of view when the aircraft climbs above 2,500 feet absolute altitude (1,500 feet for RA-335 indicators).
- Rotate DH SET knob to select DH of 200ft.
- Push and hold the indicator TEST button. The indicator pointer shall indicate 100 +/ - 10 feet, the DH annunciator shall illuminate, and the warning (OFF) flag shall come into view.
- Release the TEST button. The pointer shall return to its previous indication, the DH annunciator shall extinguish, and the warning (OFF) flag shall clear.

H.5 Operational faults

H.5.1 During the onsite visit to Turner Aviation's Aberdeen repair site, Helios determined that the most common failure seen on the radio altimeters is a broken DH selector knob.

H.5.2 Turner Aviation noted that the largest error seen on a radio altimeter returned for repair was 5 ft.

H.5.3 Within each radio altimeter, system checks are undertaken continuously to ensure system reliability. The types of faults that are monitored by these system checks vary between radio altimeter models. Some models monitor for loss of lock while more modern radio altimeters also monitor the power output of the radio altimeter.

Part 2, Annex I Computer simulation of ARA risks

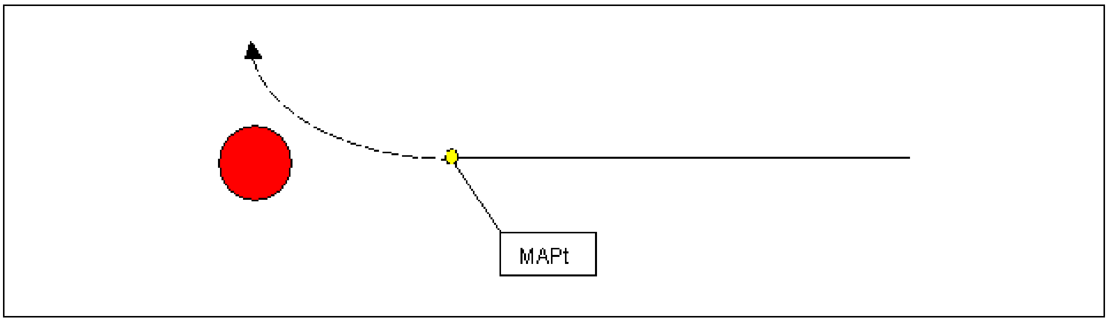
I.1 General

I.1.1 This annex describes the results of a computer simulation of the risks of an ARA. This work was conducted some years ago and was used to justify an approach minimum of 0.75NM, as widely used today. The rest of this annex reproduces a report on the simulations.

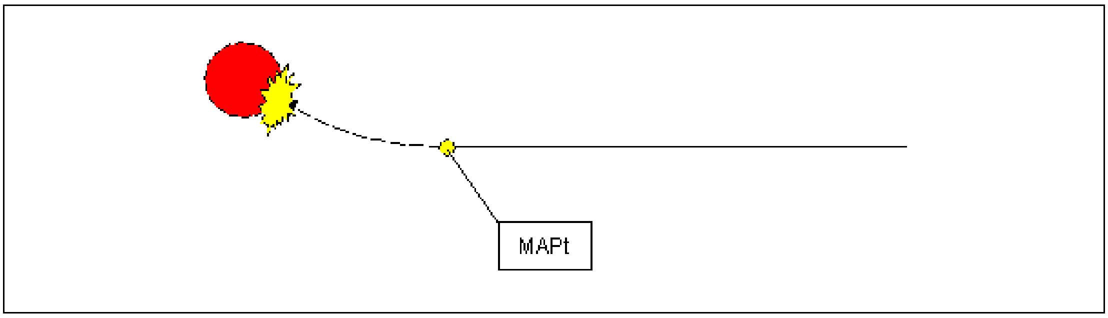
I.2 Introduction

I.2.1 The Airborne Radar Approach procedure (ARA) is described in the Joint Aviation Authorities' IEM to Appendix 1 to JAR-OPS 3.430 sub-paragraph (i) and the minima for the procedure are contained in JAR-OPS 3.430 Appendix 1. However, the method used to determine the minima of Decision Range (DR) and MDH/MDA have not been explained. It is well understood that the Decision Range is the closest that it is safe for a helicopter to approach to a large offshore structure under IFR in IMC, and still be able to carry out a go-around and turning missed approach without running the risk of colliding with the structure.

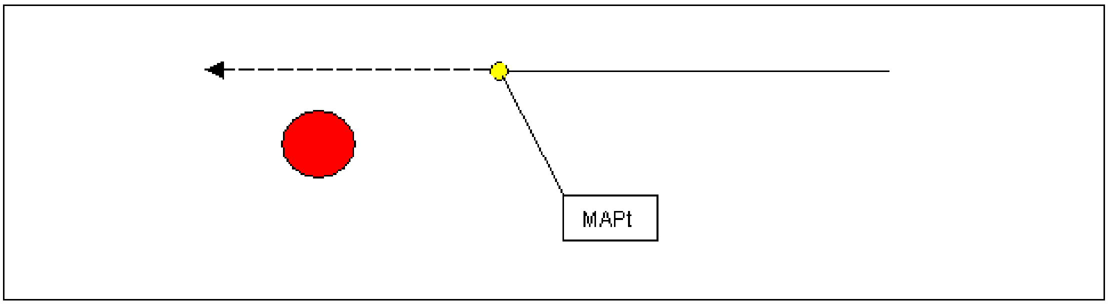
I.2.2 The simplest situation is depicted below:



I.2.3 However, tracking and ranging errors have the potential to result in the undesirable circumstances shown below:



I.2.4 But, there is also the possibility that no turn-away will be necessary:



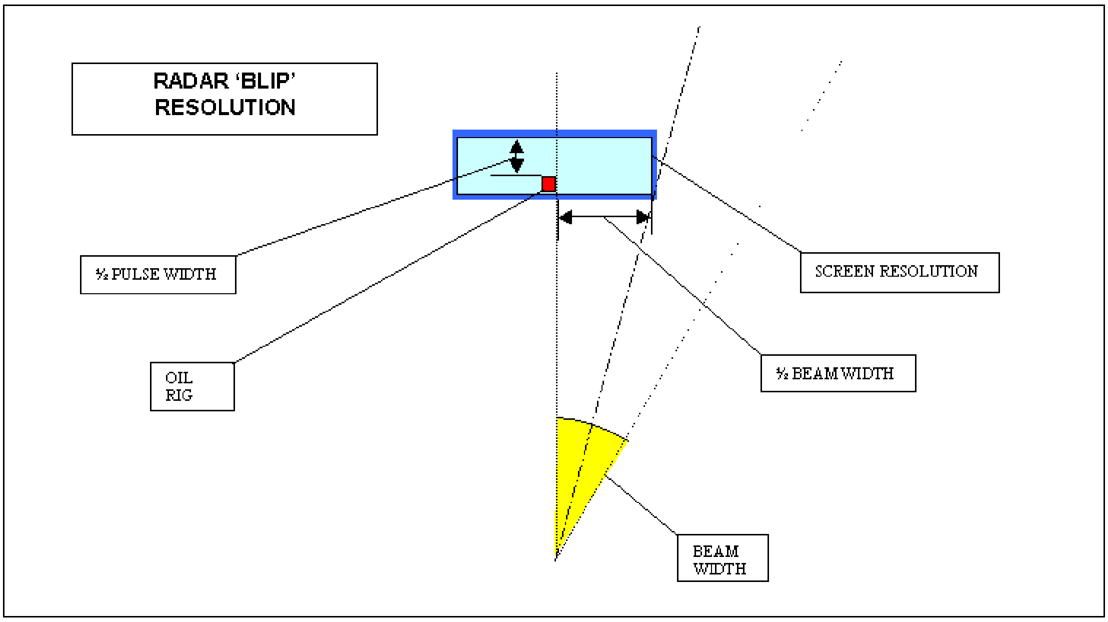
I.2.5 To solve this problem some fifteen to twenty input parameters, such as radar tracking error, the likely range of wind velocities to be encountered, radar ranging error, allowance for pilot reaction and rate of turn, etc. must be taken into account and applied to the intended flight path of the helicopter and, finally, the risk of collision must be considered. Fortunately, the acceptable risk has already been identified in the ICAO Collision Risk Model as a factor of 1 x 10^{-7}. In other words, there must be a 99.99999 % probability that the missed approach track will not infringe the horizontal dimensions assigned to the offshore installation (often referred to as an oil installation).

I.2.6 The Minimum Descent Altitude (MDA) utilising a barometric altimeter, and the Minimum Descent Height (MDH) utilising a radio altimeter can be determined after consideration of the height of possible obstacles which do not show on radar (wave height + buoys and boats with masts etc.), the standard ICAO Minimum Obstacle Clearance (MOC) of 250 ft in the case of the MDA, or the system accuracy in the case of a radio altimeter (RSS of the errors expanded to 5.2 SD), and the requirements of the Visual Landing Manoeuvre and the Turning Missed Approach.

I.3 Discussion

I.3.1 One of the first considerations should be that of the nature and resolution of the radar display:

NATURE AND RESOLUTION OF THE RADAR DISPLAY



I.3.2 Consider the diagram above. The size of the radar return from the oil installation will lie within a resolution rectangle, the size of which will depend upon the pulse duration, the beam width, the screen resolution, the gain and the tilt of the antenna. Suffice to say, that the actual oil installation will lie more or less in the centre of the 'blip' and close to its leading edge and will be surrounded by an 'electronic shadow'. To get over the difficulty of the changing nature of the radar return, the procedure calls for the final approach track to be directed, initially, towards the centre of the 'blip' and hence at the centre of the actual structure of the oil installation.

I.3.3 The missed approach point (MAPt) applicable to an airborne radar approach is normally defined by:

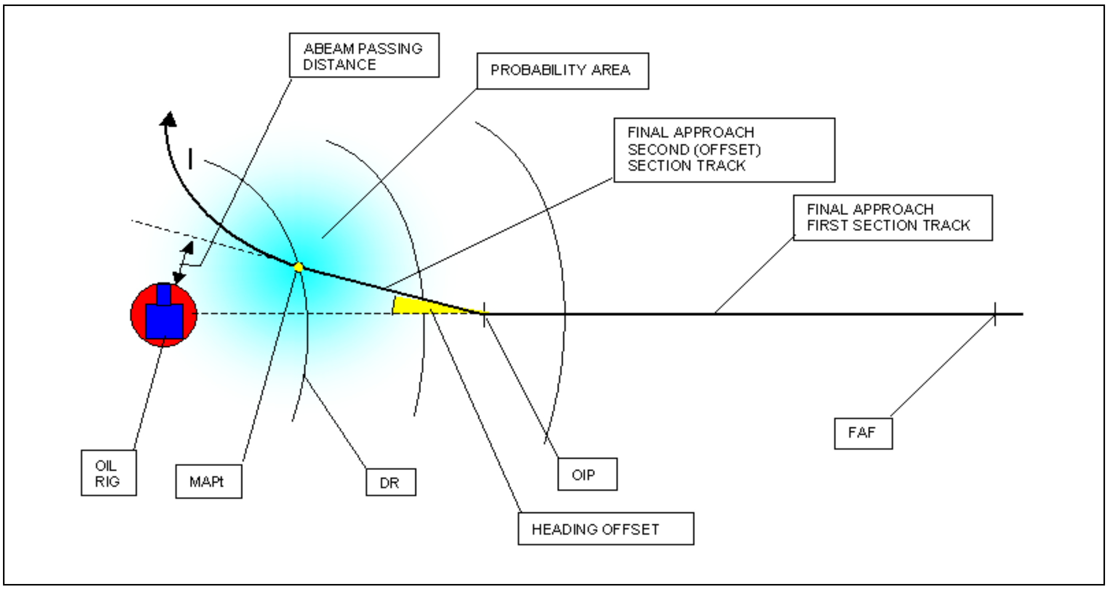
i) the lateral displacement of the offset section (second section) of the final approach track, and

ii) the decision range (DR), i.e. the minimum distance to which the helicopter can safely approach the oil installation before turning away.

I.3.4 When the visual landing manoeuvre is considered, the relative bearing of the oil installation and the space required to slow the aircraft down for the landing may dictate the choosing of a decision range which is greater than the minimum determined in the actual collision risk analysis, but this will be a largely subjective decision on the part of the procedure designers.

I.3.5 Consider now the typical form of an airborne radar approach procedure:

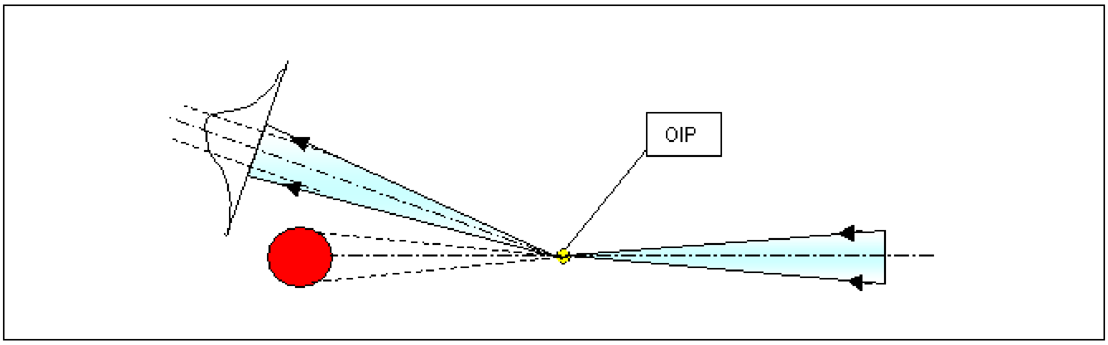
FINAL APPROACH TRACK & OFFSET INITIATION POINT



The final approach segment has two sections. The first section lies between the final approach fix (FAF) and the offset initiation point (OIP). During this phase of the flight at a 'given' airspeed (input parameter), the flight crew will carry out what is essentially a sampling process, with repeated assessment and adjustment of the aircraft heading taking place, so that by the time the OIP is reached, the drift will have been compensated and a relatively precise heading will have been determined. This will define a track that, if maintained, would take the helicopter to the centre of the oil installation. However, it is inevitable that there will be a tracking error present (input parameter - see below), taking the form of a Normal Distribution in which the mean track so identified would most often lead to the central area of the oil installation. Fewer tracks can be expected to intersect with the edges of the oil installation and a very few might miss the oil installation altogether.

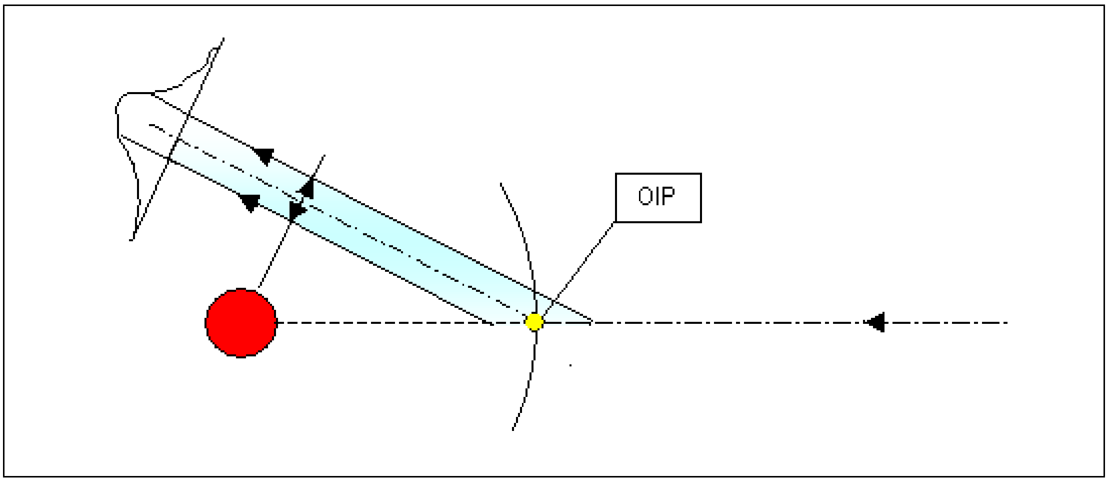
I.3.6 At the OIP a change in the aircraft heading (input parameter), by a precise number of degrees, is specified in the procedure. This will establish the aircraft on the offset section (the second section) of the final approach lying between the OIP and the MAPt. After making allowance for pilot reaction and bank establishment, a rate one turn and the anticipated drift from the range of 'given' winds (input parameter + 10 knots of undetected tailwind), the abeam passing distance can be calculated. However, the random errors in tracking applying prior to the OIP and the error in determining the OIP itself will be carried over onto the second section track and may result in the second section (offset) track passing, either closer to, or further away from the oil installation than the nominal abeam passing distance.

BEARING DERIVED ERROR

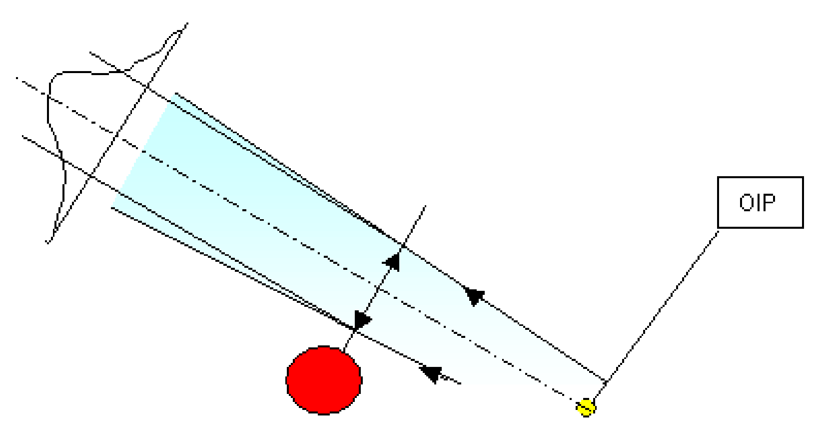


I.3.7 The OIP is defined as a radar range (input parameter), and this is considered to be subject to a mean radar ranging error (input parameter) and to a random radar ranging error (input parameter) with a Normal Distribution.

RANGE DERIVED ERROR

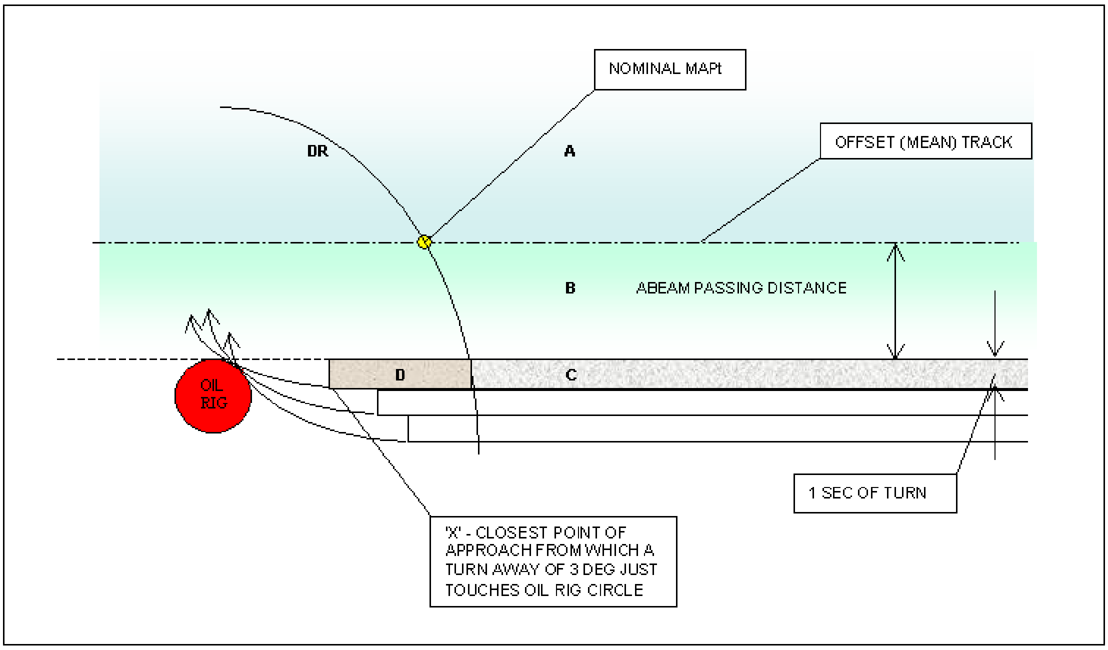


COMBINED ERROR



I.3.8 The overall effect is that the nominal MAPt lies at the intersection of an arc of radar range from the oil installation (the Decision Range - DR) and the mean position of the second section (offset) track. However, the DR will also be subject to the radar ranging errors and the effect is that the MAPt lies in a probability area defined by tracking and ranging errors with Normal Distributions.

ASSESSMENT OF THE PROBABILITY AREA



I.3.9 Consider the diagram above. The collision risk associated with a given DR is determined for a given true airspeed in a range of airspeeds and a given wind velocity in a range of winds, as follows:

I.3.10 50% of all possible MAPts will lie in Area A and will not involve any risk of collision with the oil installation, even if there is no turn-away at all.

I.3.11 P% of all possible MAPts will lie in Area B and these too will not involve any risk of collision with the oil installation even if there is no turn-away. P can be evaluated by expressing the abeam passing distance in terms of the standard deviation of the tracking error distribution (if this distance equates to 2 SD then 47.27% of all possible MAPts will lie in Area B).

I.3.12 Areas C and D comprise two sections of a narrow strip with a width that is related to 1 second of turn-away. If a turn-away of just 3 degrees is considered, such that the track just touches tangentially the edge of the circular area round the oil installation (radius is an input parameter), then both the width of the strip and distance past DR of the turn-away initiation point 'x' can be calculated. The probability of a helicopter's offset final approach track occurring in Areas C and D will be given by converting the distances of the outer and inner edges of the strip to standard deviations and thence determining the probability associated with this area (e.g. Area C: 2.1 SD - 2 SD and yields 0.48215 - 0.4727 = 0.00945.

I.3.13 The probability that a DR will be encountered somewhere along C & D is 1, with a 50% chance that it will occur before the true DR. Therefore, the probability of an MAPt occurring in Area C, which extends back from the DR to infinity will be given by 0.00945 x 0.5 = 0.00473 i.e. 0.473%.

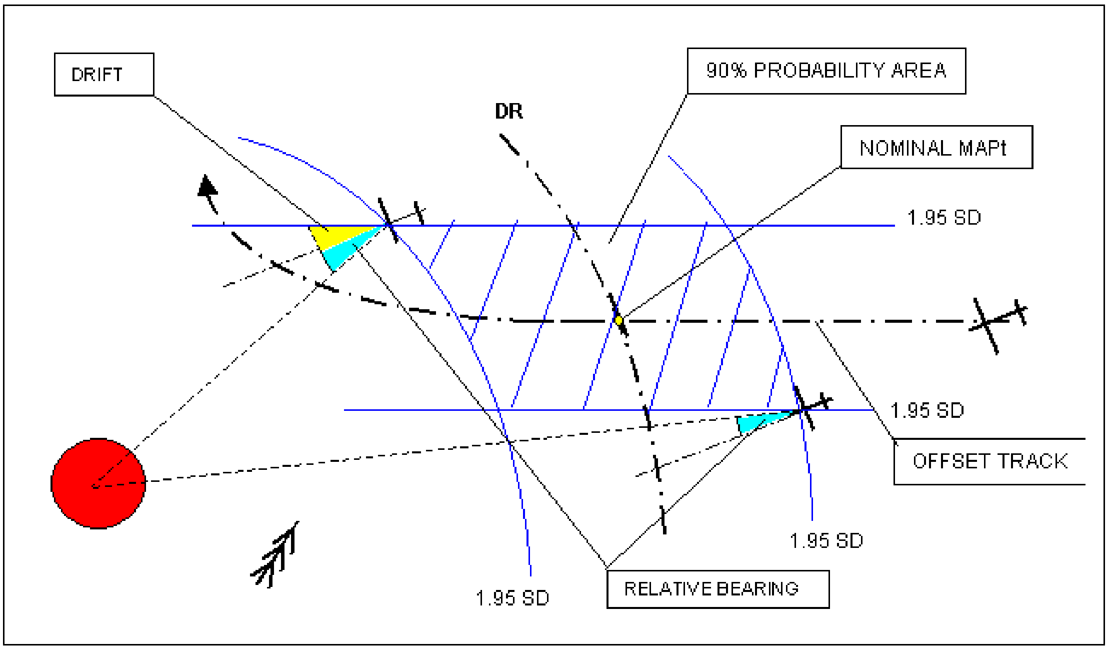
I.3.14 If the point 'x' occurs 1 SD closer to the oil installation than the DR, the probability of an MAPt occurring in Area D will be given by 0.00945 x 0.34135 = 0.00323 i.e. 0.323%

I.3.15 The MAPts identified so far in Areas A, B, C & D have no risk of collision and add up to 98.066% of all possible MAPts.

I.3.16 The process is now continued with more strips, each representing a further 3 deg of turn-way, until the desired total of turn-away (input parameter) is reached, and thereafter 1 second of flight at the maximum turn-away, until, either the figure of 99.99999% is achieved, or the latest strip to be investigated yields a probability of zero MAPts.

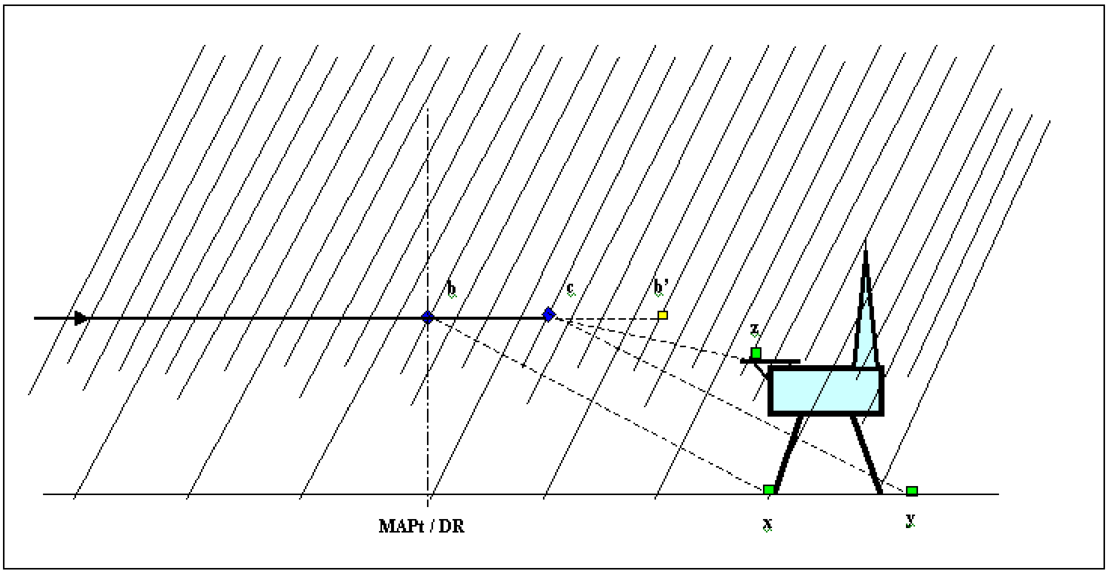
I.3.17 The computer analysis can be run in two different modes. If the DR is to be determined, then upon achieving 99.99999% probability for safe MAPts, the DR is reduced by increments of 0.1NM and the process is repeated for each DR until the factor of 0.9999999 can no longer be achieved. At this point the process is stopped and the DR at the previous increment is printed as the minimum DR for that particular wind velocity and TAS. Alternatively, the programme can be run in investigative mode and for a given DR the risk of collision will be printed.

RELATIVE POSITION OF DESTINATION AT MAPt



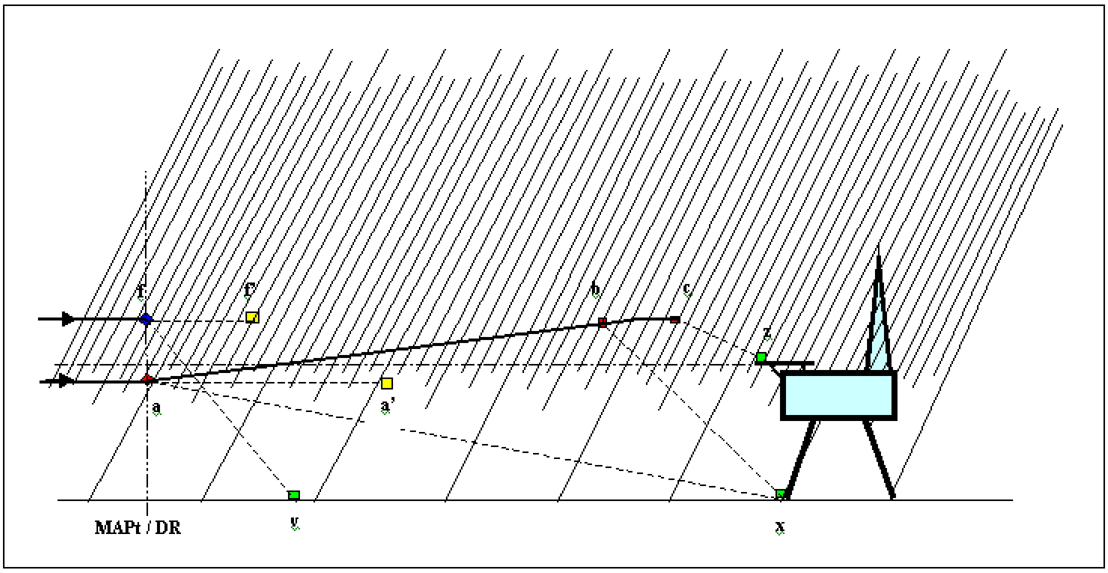
I.3.18 To give an indication of the compatibility of: DR + Offset Track + MAPt + Visual Landing Manoeuvre versus a 90% probability of success, the relative bearings of the oil installation have been calculated for MAPts occurring at 1.95 SD displaced from the mean MAPt, and summed with the drift angle being experienced in the given wind. In the example depicted above, at DR, the oil installation should be sighted somewhere between +/- 20 degrees of the nose.

MDH v VISIBILITY (FIRST CASE)



I.3.19 The diagram above depicts a situation where cloud and poor visibilities exist such that the cloud thickens and the visibility reduces with increasing height above the surface. A helicopter is shown approaching an oil platform during an ARA at an MDH which is some 50 ft or so above the elevation of the helideck. The visibility is such that on DR at (b) it is just possible for the pilot to see the base of the platform at (x) (8 intervals between the hatching lines), but note that the horizontal visibility extends only as far as (b') (8 intervals between the hatching in this direction). However, as the helicopter flies progressively closer, more of the platform will be seen, until at point (c) the surface beyond the platform will be in view at (y) and, also, the helideck will be sighted at (z) (8 intervals of the hatching).

MDH v VISIBILITY (SECOND CASE)



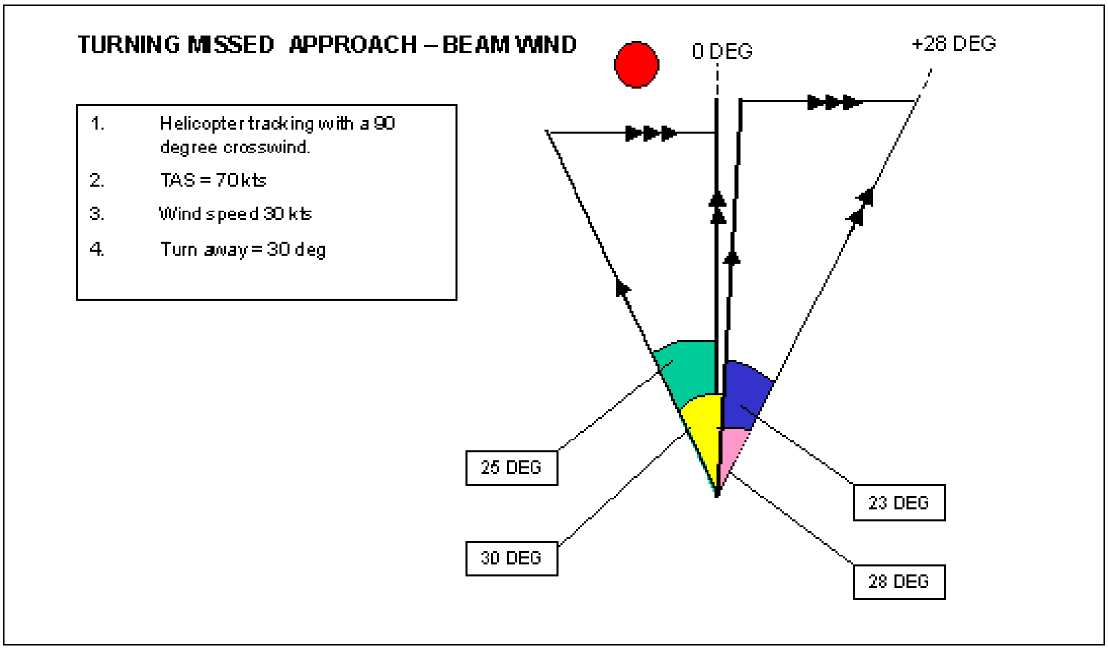
I.3.20 Consider now, the case where the cloud and visibility are denser than in the previous example.

I.3.21 The pilot of a helicopter at point (f) flying at an MDH 50 ft to 100 ft above helideck elevation will not see the oil platform. The forward limit of horizontal visibility will be point (f') and the furthest point that can be seen on the surface will be (v). This aircraft will, therefore, execute a go-around.

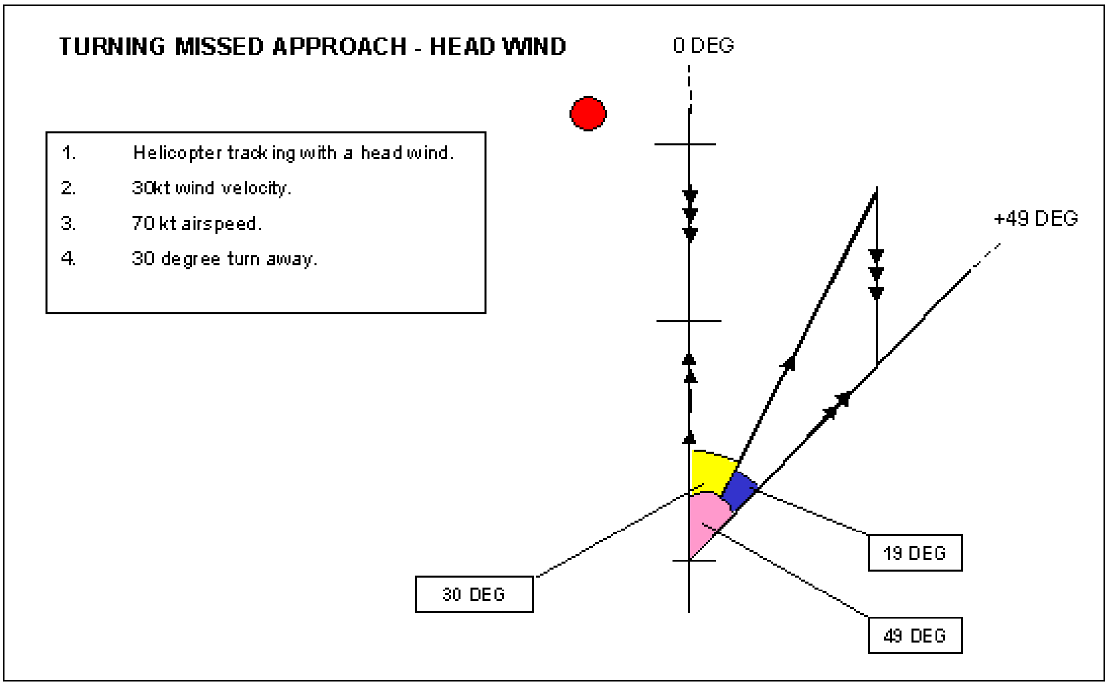
I.3.22 The pilot of a helicopter at (a) will have a limit to his horizontal visibility at (a'), but will be able to see the base of the oil platform at (x). However, as he climbs to above helideck elevation he will lose contact with the oil platform and may not regain contact with it until he is dangerously close at point (b). Nor will he make visual contact with the helideck until he closes to point (c). This is clearly unsatisfactory and indicates why the MDH/A should not be lower than 50 ft above the helideck.

I.3.23 In conclusion, it can be seen from the two cases illustrated that from an MDH/A not lower than 50 ft above the helideck, sighting of any part of the destination platform is a good indicator that a landing can be accomplished on the helideck and that it will be possible to keep the oil platform in sight throughout the manoeuvre. Conversely, an MDH/A at the same elevation or lower than the helideck is likely to result in the helicopter re-entering the cloud during the landing manoeuvre and not regaining contact with the destination until it is very close.

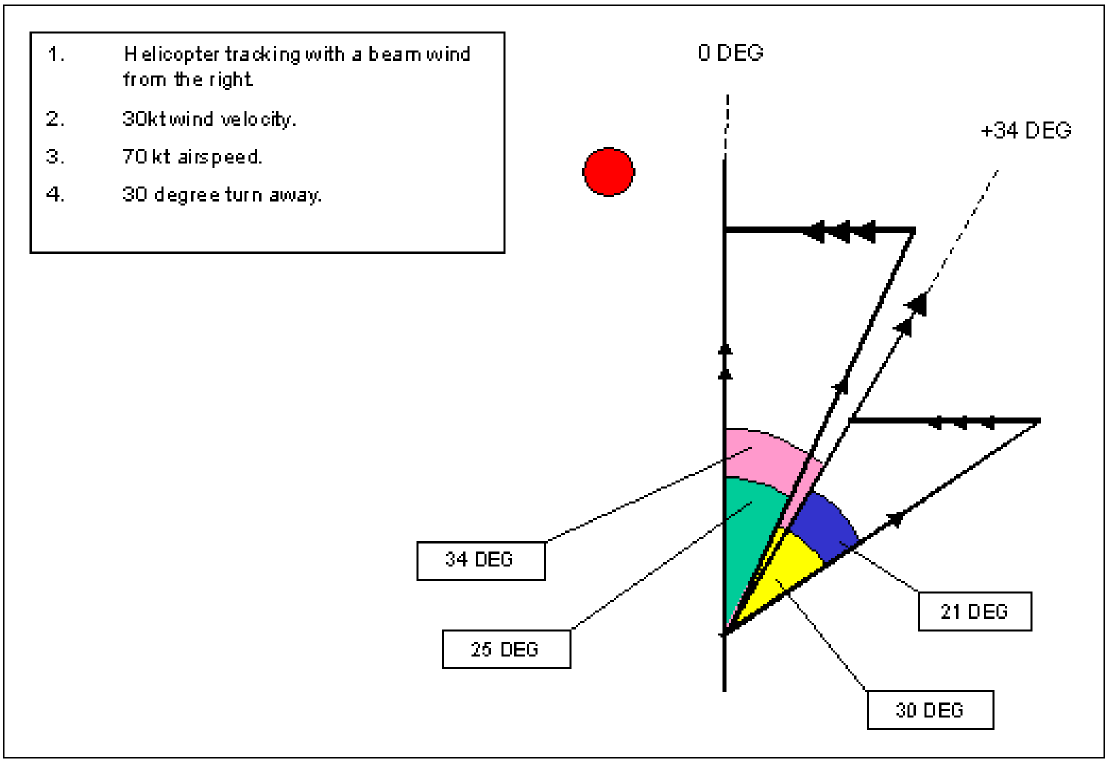
I.4 Missed approach segment



I.4.1 The above diagram depicts a helicopter maintaining a desired final approach track. In the 30 kt cross wind, the turn-away of 30 degrees has resulted in a change in track of 28 degrees.



I.4.2 In the above diagram, the helicopter is again maintaining the desired final approach track, but this time with zero drift under the influence of a 30 kt head wind. In this case, the turn-away of 30 degrees has resulted in a track change of 49 degrees.



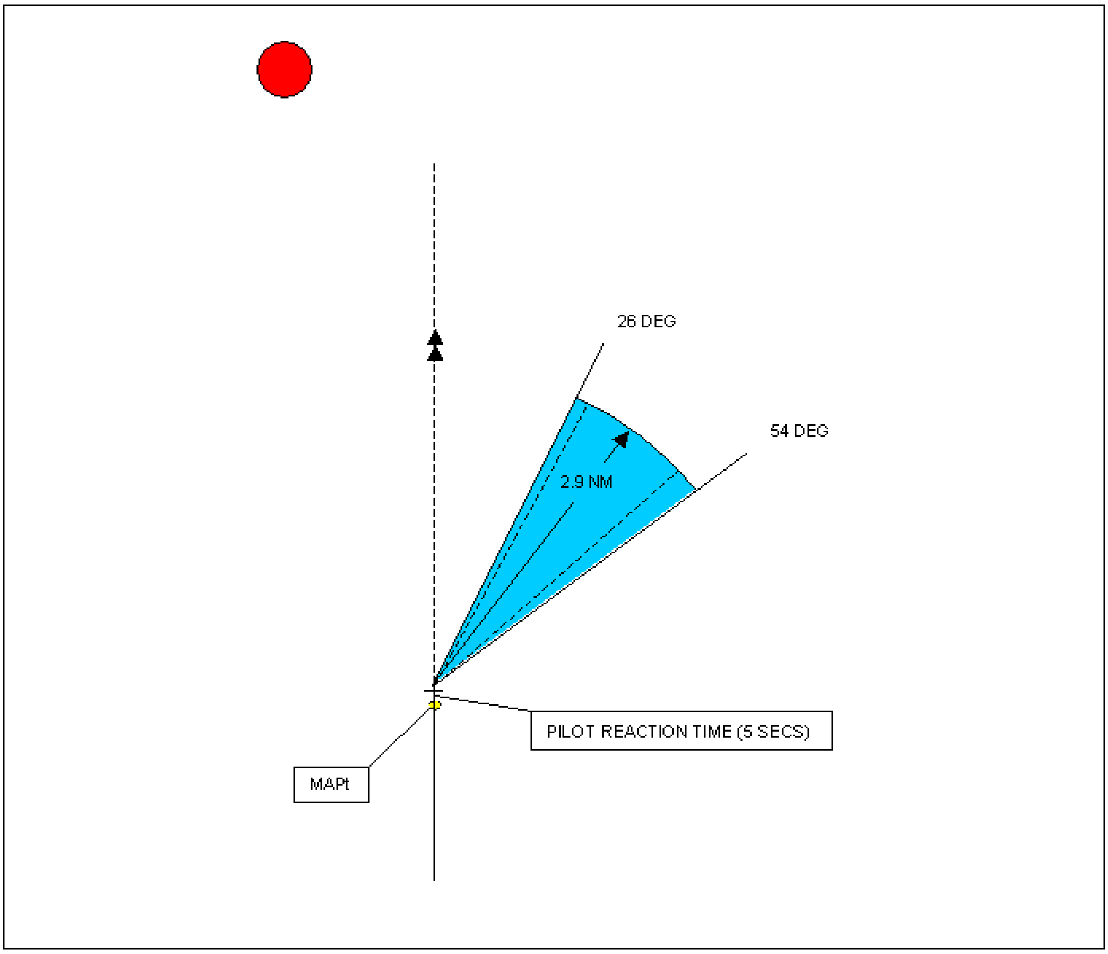
I.4.3 In the final example shown above, the helicopter is maintaining the desired final approach track with a 30 kt beam wind from the right with 25 degrees of left drift. In this case a turn-away of 30 degrees to the right has resulted in a change in track of 34 degrees to the right.

I.4.4 With this information it is now possible to construct a turning missed approach template (footprint) as follows shown below.

I.5 Turning missed approach template

I.5.1 Valid for:

Turn-away	30 deg
Pilot Reaction	180 mtrs (5 secs)
Flight Technical Error	- 2 / + 5 deg
W/V (Head & Beam)	0 - 30 kts
TAS	70 kts
Rate of Turn	Rate 1
Gradient of Climb	2.5%
MOC	132 ft
Obstacles	500 ft (assumed)
Height Gain	432 ft
Horizontal Distance	2.9 nm



I.5.2 The missed approach segment commences on go-around from the final approach. It normally begins at the MAPt, but in the event of an early go-around may start from anywhere within the final approach area. It ends when the helicopter reaches minimum en-route altitude. The manoeuvre is a "turning missed approach" which, to be compatible with the decision range of 0.75 nm, must be not less than 30 degrees. However, it should not, normally, be greater than 45 degrees. A turn away of more than 45 degrees does not reduce the collision risk factor any further, nor would it permit a closer decision range (DR). However, turns of more than 45 degrees may increase the risk of pilot disorientation and, by inhibiting the rate of climb (especially in the case of a one engine inoperative (OEI) go-around), may keep the helicopter at an extremely low level for longer than is desirable.

I.5.3 The missed approach area should be an easily identified area on the radar screen which can be confirmed to be clear of radar returns during the intermediate segment. The area should be of a shape and size big enough to contain the footprint of the helicopter as it climbs to achieve minimum vertical obstacle clearance over obstacles lying outside the area.

I.5.4 In the case of a 30 degree turn-away, the following parameters would be applicable:

(i) A range of wind velocities ranging from 0 > 30 kts and directions - 90 > 0 > +90 (the procedure is valid when oriented substantially into wind).

(ii) Length of the footprint 2.9 nm, (a climb of 432 ft from MDH of 200 ft to 500 ft obstacle environment + 130 ft MOC at a gradient of 2.5% = 2.84 nm).

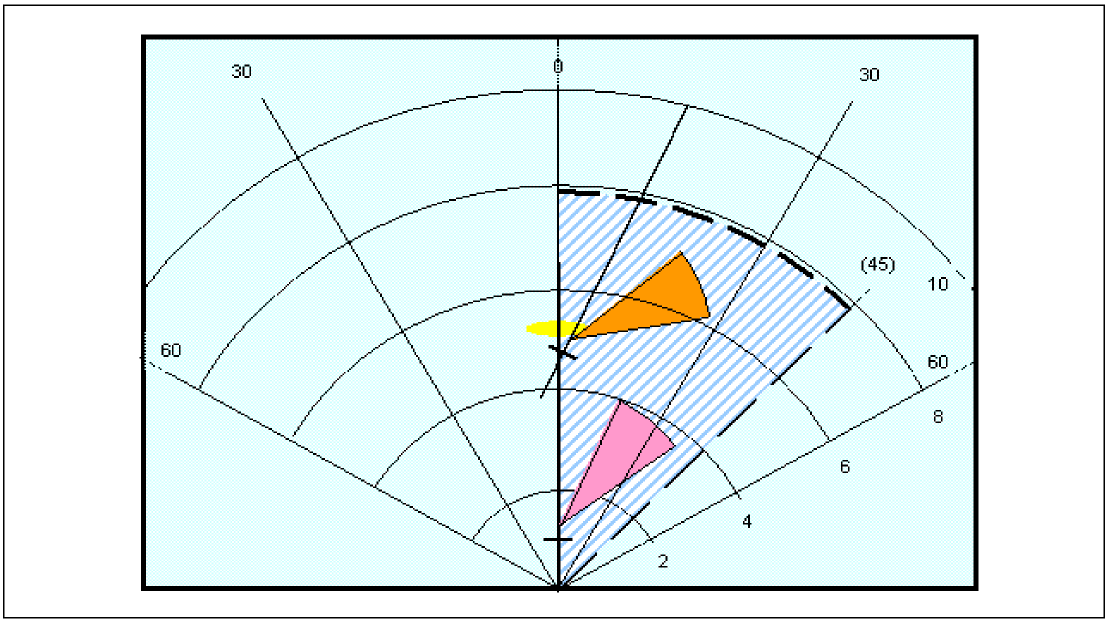
(iii) Flight technical tolerance - 2 > + 5 degrees (in case the pilot does not turn as much as 30 degrees, or turns away rather more than 30 degrees).

(iv) Pilot reaction and bank establishment time (5 seconds).

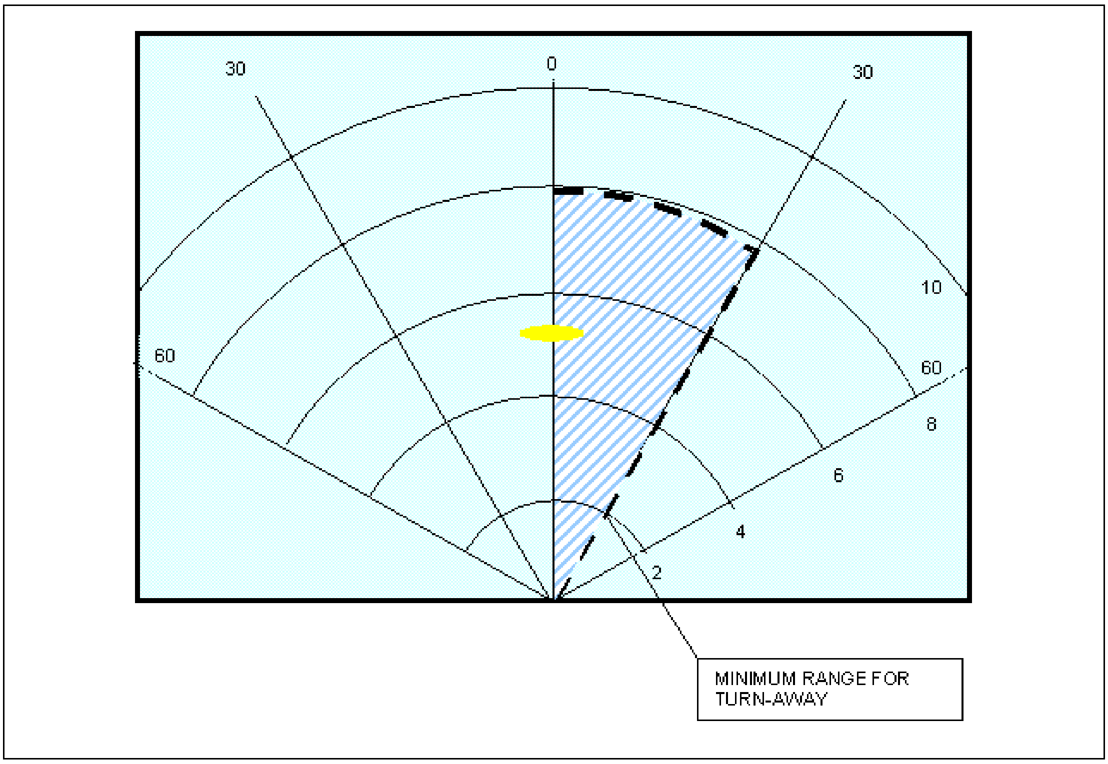
I.5.5 When flown at 70 kts, this will result in a sector 2.9 nm long lying between 26 > 54 degrees right or left of the final approach track made good.

I.5.6 The missed approach manoeuvre specified in an airborne radar approach procedure may place restrictions on when the turn-away can be commenced, but early go-arounds should not be required to close all the way to DR before turning away. In the simplest case, a missed approach area taking the form of a 45 degree sector originating from a point 5 nm short of, and extending to 3 nm beyond, the destination will normally satisfy all the above criteria when oriented left or right of the track between FAF and OIP.

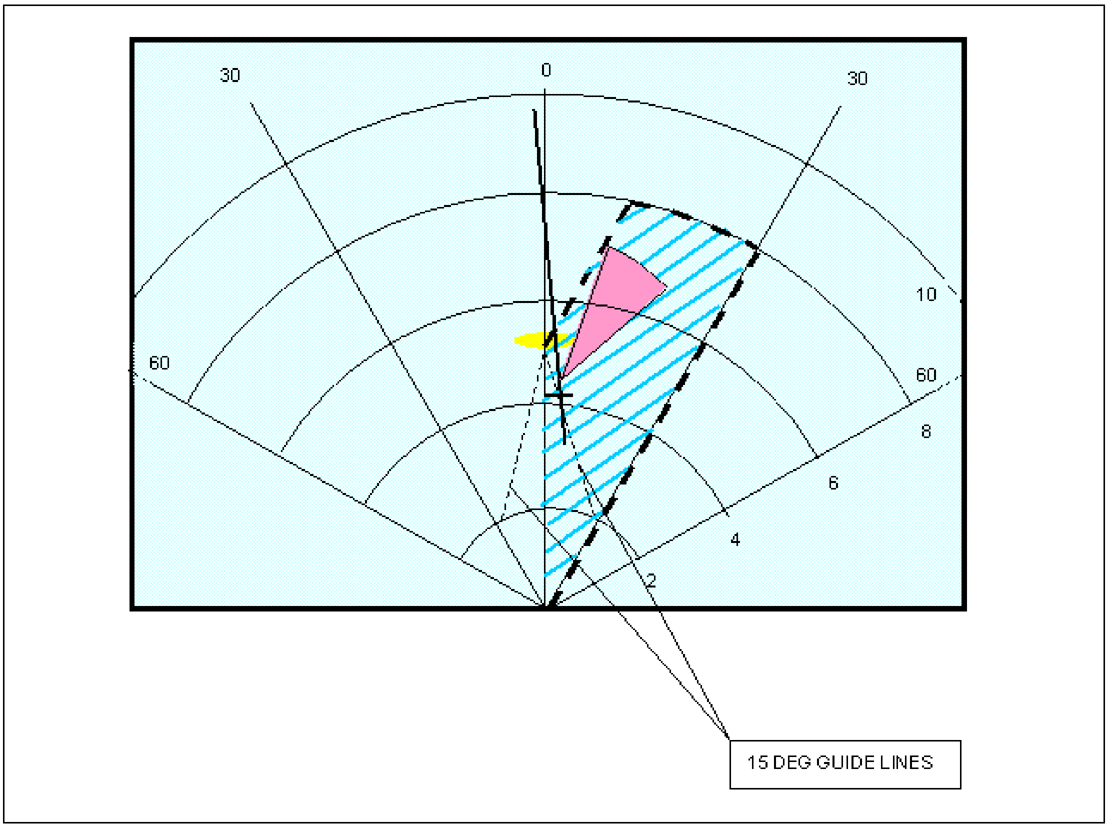
I.5.7 However, this area may be refined and reduced in size if the associated complication of the procedure during the intermediate and final approach segments can be tolerated as follows:



I.5.8 In the case of a procedure which specifies a turning missed approach of 30 degrees, the missed approach area which must be clear of all radar returns, may be reduced to a 30 degree sector originating at the 5 nm point and orientated 0 to - 30 degrees or 0 to + 30 degrees, left or right of the final approach track. However, in order to protect the aircraft in the circumstance of an early go-around, the missed approach procedure must specify a climb straight ahead until within 3 nm of the radar return for the destination before the turn-away is commenced.



I.5.9 The sectors which originate at the destination and lie within +/- 30 degrees of the extended final approach track beyond the radar return of the destination, may also be deleted from the required missed approach area, but only if the final approach prior to the OIP is constrained within +/- 15 degrees of the initial heading identified at the final approach fix. A change in heading during this segment of more than +/- 15 degrees will indicate that the approach has not been stabilised and, consequently, the standard missed approach must be executed.



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Part 2, Annex J Results from NASA flight test program

J.1 General

J.1.1 This Annex presents a brief summary of the findings of the NASA Airborne Radar Approach (ARA) Helicopter Flight Test Program [18].

J.2 Study of equipment performance by NASA

J.2.1 The NASA ARA Helicopter Flight Test Program was set up to determine:

- The total system error in range and azimuth.
- The radar system error in range and azimuth.
- The radar tracking flight technical error in range and azimuth.
- The missed approach dispersion.
- The effects on system performance of test variables:
  - Radar mode, beacon or primary.
  - Final approach profile, straight in or 15° offset.
  - Range scale setting.

J.2.2 The tests were conducted using a number of flight crew and a helicopter equipped with the Bendix RDR-1400 weather radar. The tests were conducted with the crew flying initial approaches, overheads and final and missed approach procedures. The path of the helicopter was tracked with an accuracy of six feet through a radar triangulation system to compare planned aircraft path against actual aircraft path.

J.2.3 The results presented below are for operations in 'primary' mode (i.e. weather radar mode).

Approach tracking accuracy

J.2.4 The study found that final approach track dispertions can be described by normal distributions. The 95% is about 4 NM wide at the downwind FAP and about 1 NM at 1 NM from the target. The largest component of azimuth error was flight technical error (FTE).

Azimuth accuracy

J.2.5 The azimuth accuracy was measured from samples of the angular deviation of the aircraft from the intended path at regular intervals from the target.

Table 1 Azimuth accuracy measurements

Approach type	Range	Deviation
Overall	5 nm to 0.588 nm	+5° to +6°
Offset approach	> 1.261 nm	+5° to +7.6°
Offset approach	5 nm	+7.352° (mean)
Straight-in approach	2.753 nm to 0.501 nm	+4° to +5.6°
Straight-in approach	5 nm	+0.099° (mean)

J.2.6 Other azimuth errors were also computed. The Radar Bearing Error (RBE), Flight Technical Error (FTE) and Azimuth Total System Error (ATSE) are presented below.

Table 2 Azimuth error computations

Error	Range	Mean	1 S.D.
RBE	> 1nm	-1.887° to 0.060°	1.424° to 4.431°
	0.177nm	N/A	29.416°
FTE	> 1nm	1.869° to 4.022°	8.247° to 11.384°
	0.254nm	N/A	26.187°
ATSE	> 1nm	0.986° to 2.930°	9.644 to 10.931°
	0.177nm	N/A	46.810°

Range accuracy

J.2.7 To determine the ranging errors, callouts were made as the flight crew passed designated distances from the platform. The time of the callouts was then compared to the determined range from the installation of the helicopter. The table below shows the Range Total System Error (RTSE) by the scale selected on the weather radar for the primary more.

Table 3 Range Total System Errors (RTSEs)

Range (NM)	Mean	1 S.D.
2.5	-0.0504	0.1076
5.0	-0.0378	0.2395
10.0	-0.1471	0.3584

J.2.8 The NASA report particularly noted there was a negative range bias with respect to the advertised performance of the RDR-1400. This was advertised as having a one percent bias with no mention of negative bias. The radar display resolution at the selected ranges and the frequency with which the update is made of a target contribute to the range error.

J.2.9 The experiment determined that for the primary radar mode the range errors for Radar System Error (RSE), Range Total System Error (RTSE) and Range Flight Technical Error (RFTE) are as below.

Table 4 Primary Radar Mode range errors

Range (NM)	1 S.D. RSE	1 S.D. RTSE	1 S.D. RFTE
0.50	0.098	0.101	0.024
1.25	0.039	0.107	0.100
2.00	0.039	0.109	0.102
2.50	0.051	0.220	0.214
3.00	0.060	0.124	0.109
4.00	0.051	0.261	0.256

Part 3 GPS-assisted ARA

1 Introduction

1.1 General

1.1.1 This part of the report examines the hazards associated with a GPS-assisted Airborne Radar Approach (ARA). No formal procedures for GPS-assisted ARAs existed at the time this study was initiated. An early task of the study was therefore to define a procedure applicable to the use of existing North Sea helicopter GPS equipment fits through consultation with North Sea helicopter operators and experts at the CAA. The procedure definition took into account issues such as expected workload and the capabilities of the GPS equipment.

1.1.2 The analysis in this part is structured as follows:

- Definition of GPS-assisted procedure (Section 2);
- Hazard identification (Section 3);
- Conflict scenario analysis (Section 4);
- Impact of GPS on ARA hazards (Section 5);
- Conclusions and recommendations (Section 6).

2 Definition of GPS-assisted procedure

2.1 Introduction

2.1.1 This section presents the proposed GPS-assisted ARA procedure that forms the basis for the subsequent safety analysis.

2.1.2 It should be noted that in the context of this procedure, the use of GPS is only being considered to support lateral navigation. Vertical guidance will continue to be provided by barometric altimeter/radio altimeter.

2.2 Equipment background

2.2.1 There are four types of GPS receiver currently in use in North Sea helicopters:

- Bendix King KLN-90B (Scotia);
- CMA 3000 (Bond);
- CMC 3012 (Scotia);
- Free Flight 2101 (Bristow).

2.2.2 Each has three modes of operation: en-route, terminal and approach. Each mode has a different value for full-scale CDI deflection and a different value for the RAIM alarm limit, as shown in Table 1 below:

Table 1 GPS RNAV modes

GPS mode	Full scale CDI deflection	RAIM alarm limit
En-route	5 NM	5 NM
Terminal	1 NM	1 NM
Approach	0.3 NM	0.3 NM

2.2.3 Conventionally, the receiver mode is usually set automatically based on the waypoints being flown. However, the full scale CDI deflection and RAIM alarm limit of the en-route mode was found to be insufficient for the en-route phase of offshore helicopter operation ([1]), therefore all four receiver types are required to be operated in terminal mode during the en-route phase.

2.2.4 As will be explained in the subsequent analysis, an approach should only be flown with the GPS receiver in approach mode. However, approach waypoints cannot be manually entered (see 2.3.4). The GPS receiver will only switch to approach mode if the approach waypoints are pre-stored in the navigation database as approach waypoints.

2.2.5 According to North Sea helicopter operators, none of the GPS receivers in use can be manually switched into approach mode as expected. In the case of the RNAV 2 area navigation system, the CAA insisted that the approach mode was removed from the software when GPS sensor was introduced.

2.3 Procedure description

2.3.1 The current ARA procedure relies on the use of the weather radar for navigation and obstacle clearance, and is described in detail in Part 2. The following paragraphs present the logic in determining how GPS might be used to assist the current ARA procedure.

2.3.2 It is clear that the weather radar must still be used for obstacle clearance, as it is the only sensor on board that has any capability in this regard. It therefore remains to determine to what extent GPS can be used to improve the integrity of the weather radar in general, and/or to safely enhance the navigation function.

2.3.3 In order to use GPS to assist the navigational aspects of the current ARA procedure, all the approach waypoints (IW[1], OIP and MAPt) and the destination need to be programmed into the area navigation system. In principle, the pilot may then use GPS to fly the approach by following the track guidance on the CDI.

2.3.4 However there are a number of issues that prevent the use of GPS guidance all the way to the MAPt:

- According to Eurocae ED-72 [2], the manual entry of approach waypoints (IW, OIP, MAPt and destination) into area navigation systems is not permitted; established pilot data entry error rates are too high for this critical flight phase. TSO-129a [5] does allow user defined waypoints to be entered, but they may not be defined as approach waypoints. Approach waypoints can only be selected from the pre-defined database. However, offshore approach procedures cannot be stored in a database because: 1) the approach may be to a mobile or temporary installation that is undefined in the database; 2) the final approach track is variable (see below).
- Since the ARA waypoints cannot be defined as approach waypoints with the current GPS equipment on North Sea helicopters, the area navigation system will not automatically enter approach mode. Furthermore, the GPS/RNAV computers presently in use cannot be manually switched to the approach mode either meaning that, at best, the helicopter can only be flown in terminal mode. This is not adequate for the approach, since the helicopter could get dangerously close to the destination installation due to: 1) an unannounced position error (RAIM alarm limit is 1 NM for terminal mode while the OIP and the MAPt are 1.5 NM and 0.75 NM, respectively, from the installation); 2) inadequate CDI sensitivity (the full scale CDI deflection in terminal mode is 1 NM).

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[1] IW - Inbound Waypoint. The IW is defined as a GPS waypoint 5 NM downwind from the destination.

- Offshore approaches must be oriented substantially into the wind which means that the final approach track will vary with wind direction. Even though the wind direction may be known prior to departure and the approach waypoints established and entered on the ground where data entry error rates might be acceptable, wind conditions can change during the flight. In addition, an obstacle free corridor 2 NM wide is required for the final approach path and it is not unusual for uncharted obstacles to be present. All of this means that the likelihood of the pilot needing to re-enter all the approach waypoints just before commencing the approach is relatively high, which would be unacceptable due to the relatively high risk of error.

2.3.5 An alternative to navigating the full procedure on GPS is to use it as far as the OIP and thereafter use the weather radar only. In this case, only the IW is entered into the RNAV computer, with the destination waypoint either selected from the database or entered manually (for temporary installations). This significantly reduces the crew workload and hazards caused by entering or re-entering the approach waypoints.

2.3.6 In this variation, the pilot flies from the IW towards the OIP using CDI guidance as previously described to fly the direct track from the IW to the destination. The pilot determines when the OIP is reached from the GPS range to the destination. At this point, a heading change of 10 degrees is made as for the conventional ARA procedure using the heading scale on the HSI. After the OIP, the crew revert to using the weather radar alone for the remainder of the procedure.

2.3.7 However, there are still some issues with this variation:

- GPS is still being used for navigation up to the OIP with the area navigation system in terminal mode. Again, the RAIM alarm limit of 1 NM is not sufficient to ensure separation when the helicopter is only 1.5 NM from the installation.
- Switching from navigation by GPS to navigation by weather radar at the OIP is not practical because it increases crew workload at a critical point in the approach. This is due to the need to reconcile the two different measurements and presentations of destination range and bearing information. The weather radar display shows the installation structure as a two dimensional object or 'return', and the pilot uses the distance to the nearest edge of the return to determine his range from the destination. On the other hand, GPS provides a numerical display of the distance to go to the destination waypoint, which is located somewhere on the installation but the crew may not know where. In terms of bearing to the destination, the pilot must estimate the bearing to the centre of the return on the weather radar display using the heading indicator and compare this with the numerical value of track to the destination waypoint provided by GPS. In crosswinds, this is made more difficult by the radar return not appearing directly ahead on the weather radar.

2.3.8 In order to overcome these problems it is proposed that GPS be used in the following way:

For establishing a stable track

2.3.9 GPS is used for navigation as far along the final approach path as necessary to establish a stable track and heading. As soon as this has been achieved, the crew switches to navigating by weather radar as for a conventional ARA. It is recommended that the switch to weather radar navigation is made no later than at 2.5 NM from the destination. This represents a convenient and well defined point, because it is where the crew usually change scale on the weather radar.

2.3.10 The IW is entered into the area navigation system as a range and bearing from the destination waypoint, which is either selected from the database or entered manually (for mobile/temporary installations).

2.3.11 The IW is entered into the RNAV computer as a fly-by waypoint, such that the turn onto the final approach track is anticipated and the helicopter will turn onto the track without physically overflying the IW.

2.3.12 It has been demonstrated through simulator flight trials that the angle of turn at the IW onto the final approach track does not significantly affect the time taken to establish a stable track.

2.3.13 Where possible, the turn onto the final approach track should be flown on autopilot to reduce the crew workload as much as possible.

2.3.14 In the case where the helicopter leaves the en-route sector upwind of the installation, a reciprocal approach will be required to enable the helicopter to fly the final approach track into wind. The outbound leg needs to be made sufficiently long in order to allow the helicopter to intercept the IW when the turn onto the final approach track is made. In this way a stable track can be achieved by the time the helicopter passes through the FAF at 4 NM range from the destination.

As a cross-check for reported wind

2.3.15 GPS-equipped aircraft provide the aircrew with numeric wind information and some have a continuous wind presentation on the EFIS. This wind information can be used as a cross-check of the reported wind at the installation.

As a cross-check for weather radar

2.3.16 The GPS is used for the entire approach to provide range and bearing information (acting as a pseudo VOR/DME) against which the weather radar display can be cross-checked. More confidence can be placed in a position solution that is consistent between two independent sensors as compared to one obtained from either the GPS or weather radar alone.

2.3.17 In particular, GPS cross-checks can be useful at the critical points of the approach:

- Once established on the final approach track (at 4 NM): The non-handling pilot should carry out a bearing cross-check to ensure that the two sensors are providing consistent bearing information.
- At the OIP: The non-handling pilot should cross-check the range to the destination and ensure that any discrepancy is within allowable limits. The turn is made on the basis of the position displayed on the weather radar, since the crew are no longer navigating on GPS.
- At 1 NM to go: At this point, the co-pilot will check the offset on the weather radar to ensure that the bearing to the destination is at least 15 degrees, and cross-check the GPS and weather radar ranges.

2.3.18 An important issue to consider is the maximum allowable discrepancy between GPS and weather radar information that could be tolerated on approach. This is considered in the following paragraphs.

2.3.19 It should be noted that the two sensors measure different ranges; GPS gives range and bearing to the GPS reference point, the weather radar gives range to the nearest edge and bearing nominally to the centre of the installation. This may result in the sensors giving different ranges and bearings, even though both may be working correctly. Pilots must be made aware that these discrepancies may occur and provided with guidance on the acceptable limits on discrepancies.

Maximum range discrepancy

2.3.20 Figure 1 describes how to derive the maximum range discrepancy that is expected to arise given that both sensors are working correctly. The following assumptions have been used in the calculation:

- The weather radar has a systematic bias of 250m, such that the crew always interpret the installation to be 250m further away than displayed[2] .
- The weather radar random error is +/- 250m with 95% accuracy.
- GPS random error is +/- 100m with 95% accuracy [10].
- The maximum assumed installation dimension is 200m.
- The GPS reference point can be located anywhere on the installation.

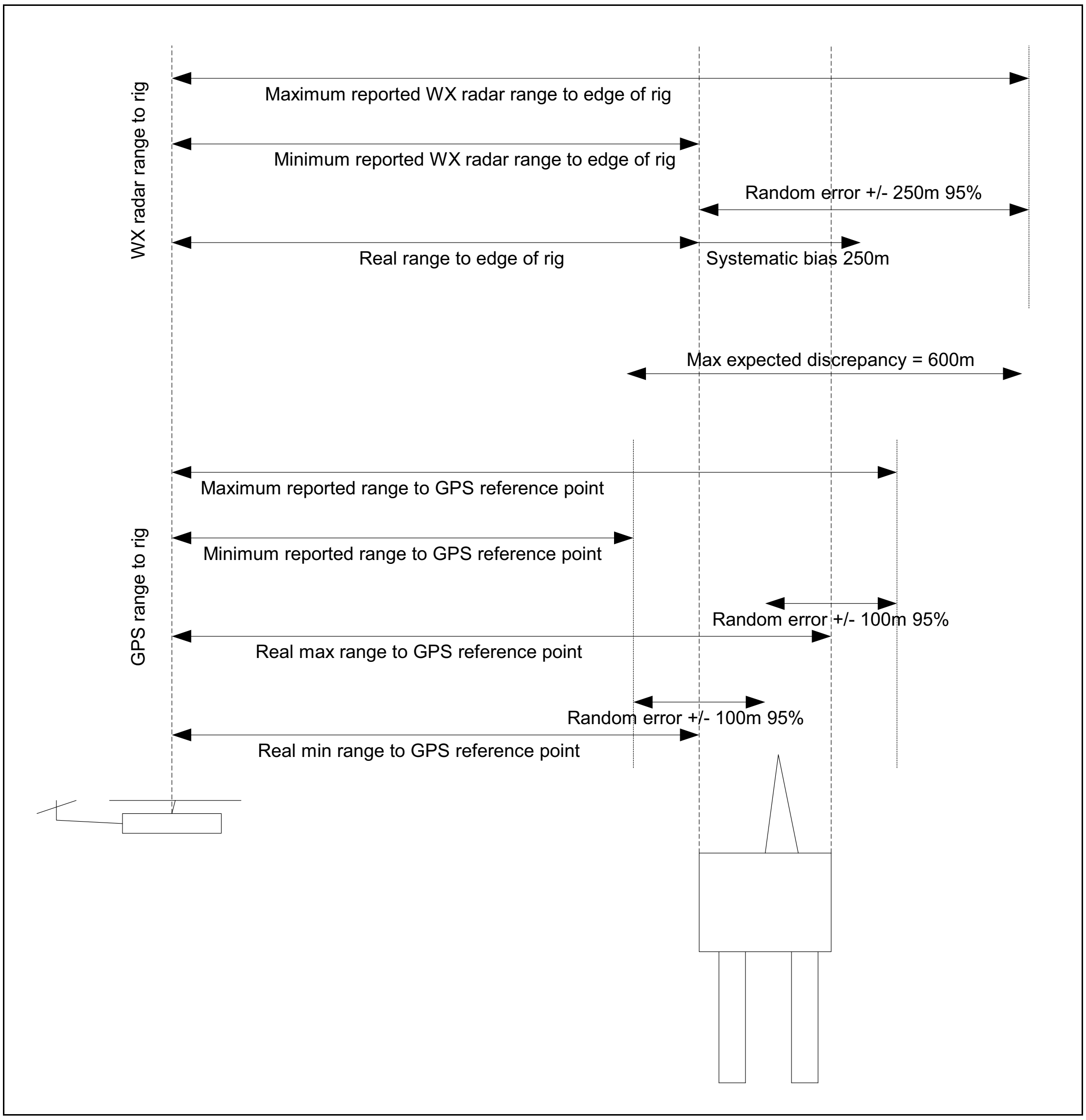

Figure 1 Expected discrepancy between GPS and weather radar range

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[2] See JAR OPS 3 Subpart E section 9.1.

2.3.21 As can be seen, the maximum expected discrepancy is 600m. This means that if the crew judge the difference between GPS and weather radar ranges to be greater than 600m, then one of the sensors is likely to be giving erroneous information.

2.3.22 In the case of a discrepancy exceeding the maximum allowable being detected anywhere up to and including the final cross-check at 1 NM, the approach must be abandoned and a go-around performed as there is no means of establishing which sensor is incorrect.

2.3.23 It should be noted that the limit of 600m is based on the theoretical performance characteristics of the two systems. The actual performance under operational conditions may differ, with subsequent effects on the discrepancy between the sensors. It is recommended that the crew record instances where the discrepancy between the sensors breaches the maximum allowed. If this is seen to occur frequently, the figure derived above may need to be reviewed.

2.3.24 It can also be seen from Figure 1 that the maximum expected discrepancy is insensitive to the dimensions of the installation provided that its dimension along the approach track is less than 600m. Offshore installations of this size are relatively unusual and should be dealt with on an individual basis.

2.3.25 On the advice of the operators, the figure for the maximum allowable range discrepancy was amended to 550m (0.3 NM) to simplify the comparison between GPS and weather radar ranges, since both sensors provide information in units of NM.

2.3.26 It should be noted that there is no consistency in the location of installation reference points on offshore installations. Popular choices are the centre of the well head, the centre of the helideck and, on multiple platform installations, the location of the link bridge connection.

2.3.27 It is therefore recommended that crew are made aware of the fact that current installation reference waypoints do not necessary indicate the location of the helideck (as might be expected). In the future, a consistent location for the installation reference point should be found and this requires some further study.

Maximum bearing discrepancy

2.3.28 In the case where the final approach track is directly into wind, the track and heading will be the same and the installation will appear directly ahead on the weather radar display. Pilots will be able to cross-check bearing by comparing readings from the GPS and the heading indicator.

2.3.29 In the case where the approach is made in cross-wind conditions, the helicopter heading will no longer be aligned with the GPS defined track, as the helicopter will now be headed slightly into wind to prevent drift away from the track.

2.3.30 In this case, the installation radar return will no longer appear directly ahead on the weather radar. Instead, it will be offset to one side, with the offset angle being dependent on the range to destination and the strength and direction of the wind. The cross-check will require the crew to estimate this angle (to the centre of the radar return), and use it together with the reading from the heading indicator to cross-check bearing against that given by the GPS.

2.3.31 The diagrams in Figure 2 illustrate the maximum expected bearing discrepancy, assuming that both sensors are working within their tolerances, for the case where the helicopter is flying the approach into a crosswind so that the track and heading do not coincide. The following assumptions have been made in the analysis:

- The weather radar has a tracking/bearing error of +/- 4.5° degrees (See JAR OPS 3 Subpart E section 9.1)
- Heading indicator error is +/- 2°.
- The accuracy to which the crew can estimate the angle of offset of the radar return is +/- 5°.
- The maximum assumed installation dimension is 200m.
- The GPS reference point can be located anywhere on the installation.
- GPS random error is +/- 100m with 95% accuracy [10].

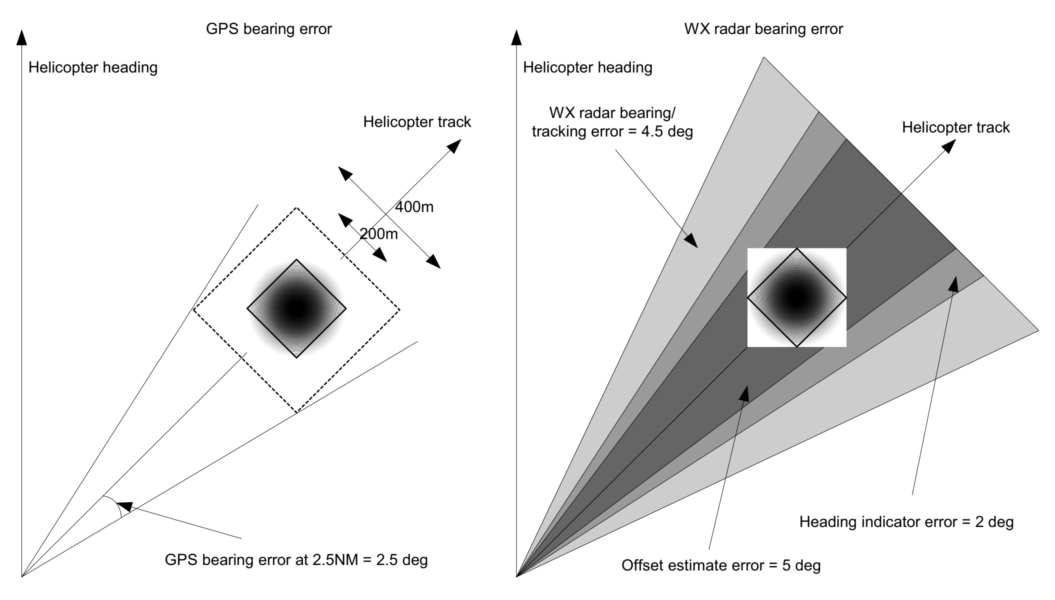

Figure 2 Expected discrepancy between GPS and weather radar bearing

2.3.32 As can be seen from the diagrams, the total weather radar bearing error can be up to 11.5 degrees. The GPS bearing error, depending on the range to destination is as follows:

- at 5 NM: 1.2 degrees;
- at 4 NM: 1.5 degrees;
- at 2.5 NM: 2.5 degrees.

2.3.33 It should be noted that the GPS error is in reality the error in the position of the helicopter relative to the installation, but for illustration purposes it has been shown on the diagram as the error in the installation position. This does not affect the calculation of bearing error. Therefore, the maximum expected bearing discrepancy between the two sensors is expected to be:

- at 5 NM: 12.7 degrees;
- at 4 NM: 13 degrees;
- at 2.5 NM: 14 degrees.

2.3.34 At 4 NM, where the bearing check is carried out, the maximum expected discrepancy is 13 degrees. It is recommended that a more conservative figure of 10 degrees be applied by the crew, to simplify the comparison in bearing between the two sensors. This figure is also more appropriate for the majority of approaches, which are made into wind, since the error in estimating the weather radar bearing will be smaller (crew will not need to estimate the offset of the radar return from the centre of the display since it will be 'on the nose' of the helicopter).

2.3.35 As for the range discrepancy, it is recommended that the crew record instances where the bearing discrepancy between sensors significantly exceeds the maximum allowed. If this is seen to occur frequently, the figure derived above may need to be reviewed.

Benefits

2.3.36 By flying this procedure, the following benefits of using GPS are realised:

- GPS provides unambiguous identification of the destination.
- The helicopter can be quickly and accurately stabilised on the correct approach track, and therefore heading, to the destination using GPS guidance. This is largely a process of trial and error using weather radar alone, and the advantages of using GPS will be particularly noticeable in the presence of cross winds.
- GPS provides an independent source of range and bearing information to the destination to check that the weather radar is free of gross errors. This improves confidence in the detection of obstacles in the approach and go-around paths as well as the location of the destination. Regular cross checks between the two sensors should be carried out from the start of the approach in order to detect any discrepancies and take appropriate action (i.e. perform a missed approach) before separation is compromised.
- Use of GPS will remove variations in approach paths up to the OIP due to wind, leading to greater consistency and accuracy. A particular benefit of this will be a reduction in the standard deviation of the cross-track error in the location of the OIP and MAPt, and hence improved separation from the destination.

2.4 Effect of procedure on flight crew roles

2.4.1 The use of GPS-assisted approaches will change some of the roles of both the handling and the non-handling pilot. In particular, the use of GPS for initially stabilising the approach track means that the non-handling crewmember will not be required to announce heading changes to the pilot, potentially reducing the possibility of flying the wrong heading due to miscommunication.

2.4.2 However, the non-handling crewmember will be required to take on the additional task of regularly cross-checking the GPS against weather radar to quickly detect any significant discrepancies.

2.4.3 The other duties of the non-handling crew member will stay largely as they are for the current ARA procedure, including:

- Monitoring the weather radar.
- Monitoring instruments to check height/track/speed.
- Monitoring the situation outside the cockpit.
- Monitoring the handling pilot's conformance using the CDI output.
- Commanding the handling pilot to initiate the offset at the OIP when the range to the destination on the weather radar is 1.5 NM.
- Ensuring that the correct offset is achieved at 1 NM range from the destination.
- Commanding the handling pilot to go around if required when the range to the destination on the weather radar is 0.75 NM.

2.4.4 The handling pilot will fly the initial part of the approach by reference to the CDI, changing to heading somewhere between the IW and the OIP, and at 2.5 NM from the destination at the latest. Otherwise, the handling pilot's responsibilities are unchanged.

2.4.5 Simulator trials of the procedure have shown that the workload for the handling pilot does not change significantly. A slight decrease in workload is expected if the procedure is flown coupled. However, this was not tested because the simulator did not have the functionality required. It is recommended that the handling pilot's workload be monitored when the procedure is put into operation.

2.4.6 The workload of the non-handling pilot was found to increase slightly due to the additional task of cross-checking between GPS and weather radar information. Additionally, it was commented that the workload might increase further due to the difficulty in reconciling position information from the two sensors in the case where there is a discrepancy. It is recommended that the non-handling pilot's workload be monitored when the procedure is put into operation.

2.5 Limitations of use

2.5.1 Caution should be exercised when using the GPS overlay procedure in strong cross winds because, there will be a significant difference between the helicopter's track and heading. In simulator trials of the GPS-assisted ARA, the switch to flying heading on the weather radar at 2.5 NM after having flown a GPS track caused confusion. The destination on the weather radar display appeared to the pilots to be offset too far, even though the track flown would have taken the helicopter to the desired OIP. It appears that pilots have less confidence in a track that they have not themselves established through trial and error, as they would with the conventional ARA. Training and/or experience should mitigate this issue.

2.5.2 However, it is proposed that this procedure should not be used for an approach more than 20 degrees out of wind.

3 Hazard identification

3.1 Introduction

3.1.1 This section presents the hazards for the proposed GPS-assisted approach procedure. It includes:

- The hazards from the ARA procedure, to consider whether the introduction of GPS would affect them.
- New hazards that would arise form the introduction of GPS. The new hazards are listed in Table 2 below.

Table 2 Hazards of GPS-assisted approach

ID	Hazard	Comment
1	Weather radar displays incorrect information.	Hazard from Part 2 (ARA analysis)
2	ADF displays incorrect information.	Hazard from Part 2 (ARA analysis)
3	Altimeter(s) displays incorrect information.	Hazard from Part 2 (ARA analysis)
4	Compass displays incorrect information.	Hazard from Part 2 (ARA analysis)
5	Wrong wind information from installation.	Hazard from Part 2 (ARA analysis)
6	Miscommunication between/with flight crew.	Hazard from Part 2 (ARA analysis)
7	Flight crew error - misinterpretation of information.	Hazard from Part 2 (ARA analysis)
8	Flight crew error - incorrect selection/operation of equipment.	Hazard from Part 2 (ARA analysis)
9	Flight crew error - distraction/inattention/ disorientation.	Hazard from Part 2 (ARA analysis)
10	Navigation database is unreliable.	New hazard due to GPS (from Part 1-en-route navigation analysis)
11	Navigation database is outdated	New hazard due to GPS (from Part 1-en-route navigation analysis)
12	Crew selects/inputs wrong waypoint(s).	New hazard due to GPS (from Part 1-en-route navigation analysis)
13	GPS Navigation is degraded.	New hazard due to GPS (from Part 1-en-route navigation analysis)
14	Loss of GPS navigation.	New hazard due to GPS (from Part 1-en-route navigation analysis)

3.2 ID1: Weather radar displays incorrect information

3.2.1 The likelihood of this hazard would be considerably reduced when using GPS to cross-check the weather radar data, particularly if GPS data is overlaid on the radar display.

3.3 ID2: ADF displays incorrect information

3.3.1 The likelihood of this hazard would be considerably reduced when using GPS to cross-check, particularly if GPS data is overlaid on the radar display.

3.4 ID3: Altimeter displays incorrect information

3.4.1 The availability of GPS would not affect this hazard.

3.5 ID4: Compass displays incorrect information

3.5.1 The availability of GPS would not affect this hazard.

3.6 ID5: Wrong wind from installation

3.6.1 The wind reported by the destination can be cross-checked using the wind information provided by GPS, reducing the likelihood of this hazard. It should be noted, however, that some differences between the wind measured at the installation and that calculated by GPS may be encountered due to the local airflow disturbances caused by the installation itself.

3.7 ID6: Miscommunication between flight crew or between installation and flight crew

3.7.1 The availability of GPS would not affect this hazard.

3.8 ID7: Flight crew error - misinterpretation of information due to clutter

3.8.1 This hazard is reduced on aircraft where there a GPS cross-check is possible, and particularly where GPS and weather radar information can be overlaid.

3.9 ID8: Flight crew error - incorrect selection/operation of equipment

3.9.1 The availability of GPS, e.g. as a cross-check of the ADF, could reduce incidents of flight crew error.

3.10 ID9: Flight crew error - distraction/inattention/disorientation

3.10.1 The availability of GPS would reduce the likelihood of disorientation because it would allow earlier and easier alignment on the final approach.

3.11 ID10: Navigation database is unreliable

3.11.1 The GPS assistance for the approach is dependent on the integrity of the navigation database.

3.11.2 For the required approach procedure, the pilot extracts the destination waypoint from the database (assuming that the position of the installation is in the database, otherwise the destination waypoint is entered manually). The IW is then entered manually as a range and bearing from the destination waypoint. An error in the destination waypoint will therefore cause an error in the location of the IW.

3.11.3 The database may contain errors. The errors may be introduced at any stage in the database development process, for example:

- Before publication in the AIP.
- If the operator adds data before loading the database onto the helicopter.

3.11.4 It may also be the case that the AIP may be correct, but that the database provider incorrectly codes the procedure or waypoints.

3.12 ID11: Navigation database is outdated

3.12.1 This hazard may arise for a number of reasons (see page 32 of [11]) such as:

- The operator does not update the database for the current AIRAC cycle.
- The database provider fails to incorporate all the changes for a new AIRAC cycle.

3.12.2 It is the operator's responsibility to ensure that the correct version of the database is loaded on the aircraft. It is the responsibility of the flight crew to check that the correct database is being used prior to departure.

3.13 ID12: Crew selects/enters wrong waypoint(s)

3.13.1 This hazard covers situations where the crew selects/enters incorrect approach waypoints. This hazard can occur in two ways:

- The pilot selects an incorrect waypoint from the database (i.e. one not corresponding to the correct destination). This is more likely to occur when temporary waypoints have been entered in the database by the previous crew and not cleared.
- The pilot makes errors in manually entering waypoints (IW or destination). It should be noted that an error in the destination waypoint would automatically result in the IW being incorrect.

3.14 ID13: GPS navigation is degraded

3.14.1 GPS navigation performance can be degraded for a number of reasons, including degradation of GPS signals-in-space, GPS sensor error, area navigation system errors, or display system errors.

3.14.2 The degradation of GPS signal-in-space performance may be caused by:

- Satellite error (e.g. clock drift) or unavailability, either notified or unannounced.
- Poor GPS constellation geometry or shielding of satellites by the helicopter fuselage, rotor blades or the destination structure.
- Intentional or unintentional interference with the GPS signal-in-space, i.e. jamming.

3.14.3 If GPS availability drops below the level required for RAIM, the position solution is no longer checked for integrity (this does not necessarily mean that navigation accuracy is reduced). According to the TSO-C129a [5] requirements for a GPS receiver, the pilot should receive a clear annunciation of such an event.

3.14.4 Other causes of degradation of GPS navigation performance include:

- GPS receiver hardware or software failures.
- Inaccuracy in the CDI output from the area navigation system.

3.14.5 Degraded navigation can be separated into two categories:

- Navigation degraded and the pilot is aware (e.g. through a system warning or cross-check).
- Navigation degraded and the pilot is not aware.

3.15 ID14: Loss of GPS navigation

3.15.1 For this hazard, GPS navigation is lost completely. This could arise due to:

- Loss of GPS signal-in-space due to system failure or jamming, or reduction in satellite availability to below the level required for position determination. Signal power could also fall to a level below that required for adequate reception.
- Loss of on-board ability to receive or analyse GPS satellite signals. This could be due to:
  - a failure of the GPS receiver;
  - a failure of the aircraft's antenna or cabling;
  - a failure of GPS (or area navigation system) display;
  - a failure of the aircraft’s wiring associated with GPS.

4 Conflict scenario analysis

4.1 Introduction

4.1.1 To analyse the operational impact of hazards, conflict scenarios are used. A conflict scenario represents an operational consequence of a hazard. Several hazards may contribute to the same operational consequence.

4.1.2 In this section, two types of Conflict Scenario (CS) are discussed:

- In Section 5, the CSs from the ARA analysis (CS1 through CS4) are reviewed to show how GPS-assistance might affect them.
- In this section, new CSs are identified that are specific to the use of GPS/RNAV.

4.1.3 Four new conflict scenarios have been identified:

- CS5a: Incorrect flight crew waypoint selection/IW entry/database checking causes deviation from intended approach path.
- CS5b: Incorrect flight crew waypoint entry causes deviation from intended approach path.
- CS6: Incorrect aeronautical data causes deviation from intended approach path.
- CS7: Incorrect position estimation causes deviation from the intended approach path.

4.1.4 Table 3 shows the links between the new conflict scenarios and the new identified hazards:

Table 3 Link between new Conflict Scenarios and hazards

Ref.	Description	CS5a	CS5b	CS6	CS7
ID10	Navigation database is unreliable			✓	
ID11	Navigation database is outdated	✓			
ID12	Crew selects/enters wrong waypoint(s)	✓	✓		
ID13	Navigation is degraded				✓
ID14	Loss of navigation				✓

4.1.5 Each of the four conflict scenarios involves the helicopter deviating from the correct approach path to the intended destination at any point from leaving en-route flight. Regular cross-checks between the weather radar and GPS position of the intended destination, however, should quickly alert the crew to any such deviation. If it should occur, the approach should be abandoned, as it may not be possible to establish which sensor is wrong.

4.1.6 The only identified risk associated with an undetected deviation from the intended approach path is that it may result in the helicopter making an approach to the wrong destination.

4.1.7 In order for this to occur, the following sequence of events must happen:

- The coordinates for the destination are incorrect or the wrong destination is entered by the pilot, or the helicopter deviates unexpectedly from the intended approach path due to undetected GPS errors, and
- the weather radar shows a credible picture of the destination (e.g. if the GPS indicates the helicopter to be on track and the helicopter is aiming for an isolated installation, even though it is the wrong installation, the weather radar will present a 'credible' picture of the installation to the pilot. Without other cross-checks, such as an NDB or other installations in the vicinity, the pilot could be led to believe that he is flying to the correct destination. It is also possible, but much less likely, that the weather radar malfunctions at the same time in such a way as to reinforce incorrect GPS information, making it impossible to detect the error[3]), and
- the flight crew fail to detect the deviation by any other means (e.g. through the use of NDB or by reference to charts).

4.1.8 Flying to the wrong installation may result in the following two hazardous events:

- The helicopter tries to land on an installation that is not ready to receive the helicopter (e.g. operations that could be hazardous to an approaching aircraft or the installation itself are being carried out). Although this situation is assigned a worst-case severity of CATASTROPHIC, the helideck status signalling system (or alternative procedures) should prevent a helicopter landing on a helideck that is in an unsafe condition. Additional workload would also be incurred in performing the go-around, particularly if this becomes necessary during the later stages of the approach.
- The helicopter comes into conflict with another helicopter in the vicinity of the installation (e.g. making an approach to or taking off from the same or an adjacent installation). This situation is assigned a severity of CATASTROPHIC.

4.2 Derivation of probabilities

4.2.1 The introduction of GPS assistance reduces the probabilities of the following hazards:

- Helicopter approaches the wrong installation. In this case, GPS provides a cross-check of the destination before the aircraft starts the final approach. The probability of occurrence is therefore assumed to reduce by a factor of 100.
- Flight-crew incorrectly locate installation on display. Again GPS provides a cross-check before the aircraft starts the final approach and the probability of occurrence is assumed to reduce by a factor of 100.

4.2.2 Table 4 summarises the probabilities for each of the above events and provides an explanation of the values used. It should be noted that the probabilities for some of the events depend on the initial cause of the deviation. All values assumed will need to be validated.

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[3] NB: Pilot training should address the issue where the destination position is confirmed by both sensors but it is wrong. Pilots must be aware that even when both sensors appear to be in agreement, there is a possibility that either both sensors are malfunctioning, or the aircraft is approaching a different installation from the one intended.

Table 4 Assumed probabilities for hazardous events

Event	Probability	Explanation
Cross-check against weather radar fails to show deviation. (CS5a).	1×10^{-1}	When an incorrect destination waypoint is selected from the database, it may be difficult for the crew to detect that the helicopter is flying to the wrong installation on the weather radar if the weather radar displays a credible picture of the destination. This is particularly likely to be a problem when flying to isolated installations, where there are no other features whose relative position may be cross-checked on the weather radar. It is assumed that in 1 in 10 of such cases the crew will not detect the deviation from the approach path to the intended destination[1] .
Cross-check against weather radar fails to show deviation. (CS5b, CS6, CS7).	1×10^{-2}	Where the destination waypoint is incorrectly coded or entered, it is unlikely that it would coincide with an actual installation. Likewise, a malfunctioning GPS receiver is not likely to direct the helicopter to an actual destination. In such a case, a cross-check of GPS against weather radar should result in the crew spotting that the coded destination is not correct, since there is unlikely to be any radar return from that location. In such a case, the probability of not detecting a deviation is judged to be reduced to 1 in 100 cases.
Flight crew fails to detect deviation by any other means. (All)	1×10^{-2}	It is assumed that in 1 in 100 cases, the crew will not spot the fact that they are flying to the wrong destination through means other than the weather radar, e.g. through the use of the NDB or through visual recognition of the installation itself or surrounding installations.
Installation unsafe and status signalling system or alternate procedure fails to warn the flight crew. (All)	1×10^{-2}	It is assumed that in 1 in 100 cases, the installation being approached (not the intended destination) will be in an unsafe state to accept a helicopter and the crew will not be warned of its state.
Another helicopter in vicinity of installation. (All)	1×10^{-2}	It is assumed that in 1 in 100 cases, there will be a helicopter either landed, approaching or departing from the particular installation being approached.
Flight crew fail to see and avoid helicopter. (All)	1×10^{-2}	It is assumed that in 1 in 100 cases, the flight crew will fail to see and avoid another helicopter in the vicinity. See Part 2, Section 4.2.5 Table 4. This probability applies independently to both helicopters in a conflict scenario giving a combined probability of 1×10^{-4}.

[1] This value is supported by the fact that around 1 in 10 installations in the northern North Sea are "isolated" - i.e. there are no other installations within a 15-mile radius.

4.3 Conflict Scenario 5a: Incorrect pilot waypoint selection/IW entry/database checking causes deviation from intended path

4.3.1 Description

4.3.1.1 In this conflict scenario, the helicopter flies an approach other than the intended one. This conflict scenario is caused by flight crew error in terms of destination waypoint selection, IW entry or database validity checking.

4.3.1.2 The two hazards that can cause this conflict scenario are ID11 (navigation database is outdated) and ID12 (crew selects wrong waypoint(s)).

4.3.1.3 It is assumed that the flight crew are aware of their current position.

4.3.2 Severity

4.3.2.1 As identified above, deviation from the intended path can result in two hazardous events. Table 5 lists these events together with their severity.

Table 5 Severity analysis for Conflict Scenario 5a

Event	Chain of events required	Severity
A) Helicopter tries to land on unsafe installation	Flight crew waypoint selection error/IW entry/ database checking causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Installation unsafe and flight crew unaware	CATASTROPHIC
B) A conflict with another helicopter	Flight crew waypoint selection error/IW entry/ database checking causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Another helicopter in vicinity of installation AND Flight crews of both helicopters fail to see and avoid each other	CATASTROPHIC

4.3.3 Probability

4.3.3.1 The probability of a deviation being caused by human error when manually inputting data (even with a manual cross-check by a second flight crew member) is discussed in [8], which estimates the probability of a deviation caused by waypoint insertion error for North Atlantic operations as being between 5 x 10^{-4} and 5 x 10^{-5} per flight. There are 5 waypoints inserted in the course of an oceanic flight, therefore the probability of a deviation caused by miss-entering one waypoint is taken to be between 1 x 10^{-4} and 1 x 10^{-5}. NB: See also Part 1, Section 4.2.3.1.

4.3.3.2 However, for the GPS-assisted procedure, the destination waypoint is selected rather than inserted (unless flying to a temporary or new installation not in the database which is covered by conflict scenario 1b), it has therefore been assumed that the probability of error will be at the lower bound of the probability range, hence the probability of incorrectly selecting the destination is taken to be 1 x 10^{-5} per approach.

4.3.3.3 For North Atlantic operations, points are inserted in a lat/long format, while for the GPS-assisted procedure, the IW is programmed in as a range and bearing from the destination. The use of the range and bearing format is also likely to reduce the risk of incorrectly programming the IW and, again, a probability of error of 1×10^{-5} per approach has been assumed for this event.

4.3.3.4 It should be noted that, because the IW is entered relative to the destination waypoint, an error in the selection or input of the destination waypoint will automatically cause the IW to be incorrect.

4.3.3.5 The same probability, 1×10^{-5} per approach, is also assumed for the event of the flight crew not spotting that the database is not valid.

4.3.3.6 Because each of the three events (errors in destination selection, IW entry, database checking) can independently lead to a deviation from the intended path, the probability covering the initiating event is $3 \times 1 \times 10^{-5}$ per approach.

4.3.3.7 The probability of occurrence of each of the two hazardous events is shown in Table 6.

Table 6 Probability analysis for Conflict Scenario 5a

Event	**Chain of events required**	**Severity**
A) Helicopter tries to land on unsafe installation	Flight crew waypoint selection error/IW entry/database checking causes deviation from intended path AND	3×10^{-5}
	Cross-check against weather radar fails to show deviation AND	1×10^{-1}
	Flight crew fails to detect deviation by any other means AND	1×10^{-2}
	Installation unsafe and flight crew unaware	1×10^{-2}
		Total: 3×10^{-10} EX. IMPROBABLE
B) A conflict with another helicopter	Flight crew waypoint selection error/IW entry/database checking causes deviation from intended path AND	3×10^{-5}
	Cross-check against weather radar fails to show deviation AND	1×10^{-1}
	Flight crew fails to detect deviation by any other means AND	1×10^{-2}
	Another helicopter in vicinity of installation AND	1×10^{-2}
	Flight crews of both helicopters fail to see and avoid each other	1×10^{-4}
		Total: 3×10^{-14} LESS THAN EX. IMPROBABLE

4.3.4 Risk tolerability

4.3.4.1 Table 7 shows the risk tolerability of conflict scenario 5a, using the modified AMJ25-1309 [3] criteria (see the study approach in Section 2 of the main report).

Table 7 Risk tolerability for Conflict Scenario 5a

Conflict Scenario 1a: Incorrect pilot waypoint selection/IW entry/database checking causes deviation from intended path		
A) CATASTROPHIC B) CATASTROPHIC	A) EX. IMPROBABLE B) LESS THAN EX. I.	A) TOLERABLE B) NEGLIGIBLE

4.4 Conflict Scenario 5b: Incorrect pilot waypoint entry causes deviation from intended path

4.4.1 Description

4.4.1.1 In this variation of conflict scenario 5, the deviation from the intended approach path is caused by the flight crew making an error in destination waypoint entry.

4.4.1.2 The two hazards that can cause this conflict scenario are ID2 (navigation database is outdated) and ID3 (crew selects wrong waypoint(s)).

4.4.1.3 It is assumed that the flight crew are aware of their current position.

4.4.2 Severity

4.4.2.1 The severity classification is as for conflict scenario 5a:

Table 8 Severity analysis for Conflict Scenario 5b

Event	**Chain of events required**	**Severity**
A) Helicopter tries to land on unsafe installation	Flight crew waypoint selection error causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Installation unsafe and flight crew unaware	CATASTROPHIC
B) A conflict with another helicopter	Flight crew waypoint selection error causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Another helicopter in vicinity of installation AND Flight crews of both helicopters fail to see and avoid each other	CATASTROPHIC

4.4.3 Probability

4.4.3.1 Because, in this case, the waypoint has to be entered rather than selected it is assumed that the probability of erroneous entry will be at the upper bound of the range specified in Section 4.3.3.1, i.e. 1×10^{-4} per approach.

4.4.3.2 Again, as for conflict scenario 5a, because the IW is entered relative to the destination waypoint, an error in the selection or input of the destination waypoint will automatically cause the IW to be incorrect.

4.4.3.3 The probability of occurrence of each of the two hazardous events is shown in Table 9.

Table 9 Probability analysis for Conflict Scenario 5b

Event	Chain of events required	Severity
A) Helicopter tries to land on unsafe installation	Flight crew waypoint entry error causes deviation from intended path AND	1×10^{-4}
	Cross-check against weather radar fails to show deviation AND	1×10^{-1}
	Flight crew fails to detect deviation by any other means AND	1×10^{-2}
	Installation unsafe and flight crew unaware	1×10^{-2}
		Total: 1×10^{-9} EX. IMPROBABLE
B) A conflict with another helicopter	Flight crew waypoint entry error causes deviation from intended path AND	1×10^{-4}
	Cross-check against weather radar fails to show deviation AND	1×10^{-1}
	Flight crew fails to detect deviation by any other means AND	1×10^{-2}
	Another helicopter in vicinity of installation AND	1×10^{-2}
	Flight crews of both helicopters fail to see and avoid each other	1×10^{-4}
		Total: 1×10^{-13} LESS THAN EX. IMPROBABLE

4.4.4 Risk tolerability

4.4.4.1 Table 10 shows the risk tolerability of conflict scenario 5b, using the AMJ25-1309 [3] criteria.

Table 10 Risk tolerability for Conflict Scenario 5b

Conflict Scenario 1b: Incorrect pilot waypoint entry causes deviation from intended path		
Severity	**Probability**	**Result**
A) CATASTROPHIC B) CATASTROPHIC	A) EX. IMPROBABLE B) LESS THAN EX. I.	A) TOLERABLE B) NEGLIGIBLE

4.5 Conflict Scenario 6: Incorrect aeronautical data causes deviation from intended path

4.5.1 Description

4.5.1.1 This conflict scenario considers the case where the helicopter crew are presented with incorrect destination information from the database. However, because the IW is programmed in as a range and bearing from the destination, an error in the destination will have a knock-on effect on the IW.

4.5.2 Severity

4.5.2.1 Table 11 presents the severity classification for conflict scenario 6.

Table 11 Severity analysis for Conflict Scenario 6

Event	Chain of events required	Severity
A) Helicopter tries to land on unsafe installation	Incorrect aeronautical data causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Installation unsafe and flight crew unaware	CATASTROPHIC
B) A conflict with another helicopter	Incorrect aeronautical data causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Another helicopter in vicinity of installation AND Flight crews of both helicopters fail to see and avoid each other	CATASTROPHIC

4.5.3 Probability of undetected deviation

4.5.3.1 Navigation databases are required to have integrity of 10^{-5} by ICAO Annexes 11 and 15. However studies (see page 41 of [4]) have highlighted discrepancies in data from various database providers and data from AIPs, and concluded that some data are outside ICAO Annex 15 tolerances. [8] estimates a probability of database error of 2×10^{-4}, and this probability is used here. However, the North Sea data changes very infrequently therefore the probability of errors should be reduced. We therefore assume a figure of 2×10^{-5}.

Table 12 Probability analysis for Conflict Scenario 6

Event	Chain of events required	Severity
A) Helicopter tries to land on unsafe installation	Incorrect aeronautical data causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Installation unsafe and flight crew unaware	2×10^{-5} 1×10^{-1} 1×10^{-2} 1×10^{-2} **Total: 2×10^{-10}** EX. IMPROBABLE
B) A conflict with another helicopter	Incorrect aeronautical data causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Another helicopter in vicinity of installation AND Flight crews of both helicopters fail to see and avoid each other	2×10^{-5} 1×10^{-1} 1×10^{-2} 1×10^{-2} 1×10^{-4} **Total: 2×10^{-14}** LESS THAN EX. IMPROBABLE

4.5.4 Risk tolerability

4.5.4.1 Table 13 shows the risk tolerability of conflict scenario 6, using the modified AMJ25-1309 [3] criteria (see the study approach in Section 2 of the main report).

Table 13 Risk tolerability for Conflict Scenario 6

Conflict Scenario 6: Incorrect aeronautical data causes deviation from intended path		
Severity	**Probability**	**Result**
A) CATASTROPHIC B) CATASTROPHIC	A) EX. IMPROBABLE B) LESS THAN EX. I.	A) TOLERABLE B) NEGLIGIBLE

4.5.4.2 In order to minimise the risk from incorrect aeronautical data, the operators should implement navigation database integrity checks using appropriate software tools or approved manual procedures to verify data relating to waypoints used for offshore operations. Such checks are in addition to any checks previously performed by the Aeronautical Information Services, unapproved navigation database suppliers, or navigation equipment manufacturers.

4.6 Conflict Scenario 7: Incorrect position estimation causes the deviation from the correct approach path

4.6.1 Description

4.6.1.1 This conflict scenario considers the case where the helicopter deviates from its intended approach due to incorrect or unavailable position information from the navigation system. This assessment focuses on loss or degradation of GPS but also identifies other system failures.

4.6.1.2 The two hazards that cause this conflict scenario are ID13 (navigation is degraded) and ID14 (loss of navigation). The following cases are considered:

- Case 1: RAIM unavailable (crew aware);
- Case 2: RAIM limit exceeded (crew aware);
- Case 3: RAIM limit exceeded/RAIM unavailable (crew unaware);
- Case 4: Position estimate not available.

4.6.2 Case 1: RAIM unavailable (crew aware)

4.6.2.1 If the satellite availability drops below the level required for RAIM, TSO-C129a [5] states that the flight crew should receive a warning. In such a case, the GPS position provided is no longer integrity assured, and therefore the crew would not be alerted to an erroneous position solution. Although loss of RAIM does not necessarily mean that GPS navigation is degraded, it is recommended that GPS be cross checked against other sources during RAIM outages.

4.6.2.2 Because this failure is announced to the crew, the probability that it will cause an undetected deviation is negligible. It has to be remembered that for this approach procedure GPS is used in terminal mode with a RAIM alarm limit of 1 NM. Hence only gross errors would be annunciated, which would most likely be detected by the flight crew anyway.

4.6.2.3 The crew should discontinue the approach in the case of unavailability of RAIM.

4.6.3 Case 2: RAIM alarm limit exceeded (crew aware)

4.6.3.1 TSO-C129a [5] states that if the error in the position solution from GPS exceeds 1 NM (area navigation system in terminal mode), a warning should be annunciated to the flight crew within a maximum of 10 seconds of the deviation being detected.

4.6.3.2 Analysing historical data from the FAA's GPS performance analysis and applying error characteristics applicable to an airborne GPS receiver, [7] shows that the likelihood of a position error of more than 1 NM is smaller than 10^{-7}.

4.6.3.3 Previous studies carried out for the CAA [6] have also identified singular errors that have occurred within the GPS system. However, the large majority of these would not be of sufficient magnitude to exceed the RAIM alarm limit. Additionally, many of the error events recorded were also associated with previous generation GPS satellites that have since been replaced.

4.6.3.4 Because this failure is announced to the crew, the probability that it will cause an undetected deviation is considered to be negligible.

4.6.4 Case 3: RAIM limit exceeded/RAIM unavailable (crew unaware)

4.6.4.1 Typical failures are caused by the receiver not detecting when the RAIM limit has been exceeded or introducing an unrelated error that exceeds RAIM limits.

4.6.5 Case 4: Position estimate not available

4.6.5.1 This case can arise because of a loss of the GPS signal-in-space or equipment failure. TSO-C129a [5] states that if the GPS system fails (either the signal-in-space or the receiver), the crew will be automatically alerted by the GPS avionics. The crew is therefore aware that position is unavailable.

4.6.5.2 Because this failure is announced to the crew, the probability that it will cause an undetected deviation is negligible. If this event occurs, the approach should be abandoned and a go-around initiated. Although there is no suggestion that the weather radar information is unreliable, the earlier stages of the approach prior to the loss of GPS may have been compromised by inaccurate GPS position information, hence the need to abandon the approach.

4.6.6 Severity

Case 3: RAIM limit exceeded/RAIM unavailable (crew unaware)

4.6.6.1 Case 3 is the only case out of the four where the failure is not announced to the crew, and is therefore the only case that needs to be considered when evaluating the severity and probability of an undetected deviation. Table 14 shows the severity classification for this conflict scenario.

Table 14 Severity analysis for Conflict Scenario 7

Event	Chain of events required	Severity
A) Helicopter tries to land on unsafe installation	Unannounced GPS receiver error causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Installation unsafe and flight crew unaware	CATASTROPHIC
B) A conflict with another helicopter	Unannounced GPS receiver error causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Another helicopter in vicinity of installation AND Flight crews of both helicopters fail to see and avoid each other	CATASTROPHIC

4.6.7 Probability of undetected deviation (Case 3)

4.6.7.1 This event occurs either because of a failure in the GPS signal-in-space which is not detected and announced to the crew by the receiver (through RAIM or otherwise), or because of an unannounced failure of the GPS receiver. Note that although the crew are unaware of the initial failure, they may detect the failure later.

4.6.7.2 The MORs [9] show only one receiver failure which was not announced to the crew (see incident on 16/02/1999 in Part 2, Annex B) which suggests an integrity failure rate of order 10^{-5} per flight hour. Given that an approach takes approximately 6 minutes (6 NM from the IF at 60 knots), the probability of a GPS failure during an approach is taken to be 1×10^{-6}. Further validation of this figure is recommended.

4.6.7.3 Unannounced GPS signal-in-space errors are those that would occur which RAIM or other integrity assurance measures would not detect. TSO-C129a [5] GPS receivers are designed to detect 99.9% of all significant satellite failures. Therefore the probability of a missed detection is 1×10^{-3}. However, significant satellite failures (e.g. clock drift) are themselves infrequent. It is assumed that undetected GPS signal in space errors are infrequent compared with the receiver failure rate shown above.

Table 15 Probability analysis for Conflict Scenario 7

Event	Chain of events required	Severity
A) Helicopter tries to land on unsafe installation	Unannounced GPS receiver error causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Installation unsafe and flight crew unaware	1×10^{-6} 1×10^{-1} 1×10^{-2} 1×10^{-2} **Total: 1×10^{-11}** LESS THAN EX. IMPROBABLE
B) A conflict with another helicopter	Unannounced GPS receiver error causes deviation from intended path AND Cross-check against weather radar fails to show deviation AND Flight crew fails to detect deviation by any other means AND Another helicopter in vicinity of installation AND Flight crews of both helicopters fail to see and avoid each other	1×10^{-6} 1×10^{-1} 1×10^{-2} 1×10^{-2} 1×10^{-4} **Total: 1×10^{-15}** LESS THAN EX. IMPROBABLE

4.6.8 Risk tolerability

4.6.8.1 Table 16 shows the risk tolerability of conflict scenario 7, using the modified AMJ25-1309 [3] criteria (see the study approach in Section 2 of the main report).

Table 16 Risk tolerability for conflict scenario 7

Conflict Scenario 7 (case 3): Unannounced GPS receiver error causes deviation from intended path		
Severity	**Probability**	**Result**
A) CATASTROPHIC B) CATASTROPHIC	A) LESS THAN EX. I. B) LESS THAN EX. I.	A) NEGLIGIBLE B) NEGLIGIBLE

5 Impact of GPS on ARA hazards

5.1 Introduction

5.1.1 This section updates the conflict scenarios from Part 2 (ARA procedure) using the proposed GPS-assisted ARA procedure.

5.2 Changed assumptions

5.2.1 The introduction of GPS assistance reduces the probabilities of the following hazards:

- Helicopter approaches the wrong installation. In this case, GPS provides a cross-check of the destination before the aircraft starts the final approach. The probability of occurrence is therefore assumed to reduce by a factor of 100.
- Flight-crew incorrectly locate installation on display. Again GPS provides a cross-check before the aircraft starts the final approach and the probability of occurrence is assumed to reduce by a factor of 100.

5.2.2 In addition, a new mitigation is added to the CS4:

- Flight crew fail to observe the discrepancy between radar and GPS position. This is assumed to have a probability of 10^{-2}.

5.2.3 All other probabilities and frequencies are unchanged.

5.3 Impact on risk tolerability

5.3.1 The summary risk matrix from Part 2, Section 5.1.1, Table 18 is reproduced in Table 17 on the next page, updated with the changed assumptions. Changed values are underlined.

Table 17 ARA procedure Conflict Scenarios updated with GPS

Conflict Scenario 1: The helicopter approaches the wrong installation			
	Severity	**Probability**	**Result**
1a. The flight crew approach the wrong installation and come into conflict with another helicopter.	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE (2 x 10^{-12})	NEGLIGIBLE
1b. The flight crew land on the wrong installation and it is in an unsafe condition.	CATASTROPHIC	EXTREMELY IMPROBABLE (2 x 10^{-11})	TOLERABLE
Conflict Scenario 2: The helicopter comes into conflict with the sea			
	Severity	**Probability**	**Result**
2a. The helicopter comes into conflict with the sea due to crew error.	CATASTROPHIC	LESS THAN EXTREMELY IMPROBABLE (1 x 10^{-11})	NEGLIGIBLE
2b. The helicopter comes into conflict with the sea due to altimeter failure.	CATASTROPHIC	EXTREMELY IMPROBABLE (1 x 10^{-9})	TOLERABLE
Conflict Scenario 3: The helicopter comes into conflict with another obstacle			
	Severity	**Probability**	**Result**
3a. The helicopter comes into conflict with an obstacle due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE (1 X 10^{-9})	TOLERABLE
3b. The helicopter comes into conflict with an obstacle due to the absence of the obstacle on the weather radar display.	CATASTROPHIC	EXTREMELY IMPROBABLE (1 x 10^{-9})	TOLERABLE
Conflict Scenario 4: The helicopter comes into conflict with the destination installation			
	Severity	**Probability**	**Result**
4a. The helicopter comes into conflict with the destination installation due to flight crew error.	CATASTROPHIC	EXTREMELY IMPROBABLE (1 X 10^{-10})	TOLERABLE
4b. The helicopter comes into conflict with the destination installation due to unannunciated weather radar malfunction.	CATASTROPHIC	EXTREMELY IMPROBABLE (1 x 10^{-10})	TOLERABLE

5.3.2 The consequence of adding in the GPS cross-checks is to change one CS from TOLERABLE to NEGLIGIBLE, and three CSs from UNACCEPTABLE to TOLERABLE.

6 Conclusions and recommendations

6.1 Introduction

6.1.1 This report has examined the main hazards associated with using GPS to assist the current ARA procedure. The role of GPS has been assessed from two perspectives:

- Whether the use of GPS assistance introduces any unacceptable risks.
- Whether the use of GPS assistance mitigates any of the hazards in the ARA.

6.2 Summary of GPS-assisted ARA procedure

6.2.1 A GPS-assisted ARA procedure has been proposed in this report. This involves the following:

- Selection from the area navigation system database or manual entry of the destination.
- Manual entry of the IW, as a range and bearing from the destination.
- Operation of the GPS equipment in terminal mode.
- Comparison of weather radar and GPS range and bearing data, to cross-check the location of the destination.
- Use of GPS guidance (via the CDI) to guide the aircraft towards the IW.
- Use of GPS guidance (via the CDI) from the IW towards the OIP, using the CDI to establish the helicopter on the correct approach track and, hence, heading.
- Transition from GPS guidance to navigation on headings once the track is stabilised and before reaching 2.5 NM range from the destination.
- Use of GPS range and bearing to the destination during the first segment of the final approach (IW to OIP) to cross-check weather radar information (for correct 'painting' of destination and, hence, other obstacles).
- Use of GPS range to the destination to enhance confidence in the weather radar determination of arrival at OIP and MAPt.
- Use of GPS range and bearing to the destination to monitor separation from the destination.

6.3 Hazards introduced by GPS assistance

6.3.1 The new procedure was not found to introduce any unacceptable risks. Table 18 below summarises the hazards and the risk tolerability of the new procedure. It can be seen that all of the new hazards are no worse than 'TOLERABLE'.

Table 18 Hazards and risk tolerability

Initial cause of deviation	Event A Helicopter tries to land on unsafe installation	Event B Conflict with another helicopter
CS5a: Incorrect flight crew waypoint selection/IW entry/database checking causes deviation from intended path	TOLERABLE	NEGLIGIBLE
CS5b: Incorrect flight crew waypoint entry causes deviation from intended path	TOLERABLE	NEGLIGIBLE

Table 18 Hazards and risk tolerability (Continued)

Initial cause of deviation	**Event A Helicopter tries to land on unsafe installation**	**Event B Conflict with another helicopter**
CS6: Incorrect aeronautical data causes deviation from intended path	TOLERABLE	NEGLIGIBLE
CS7: Incorrect position estimation causes deviation from the correct approach path	NEGLIGIBLE	NEGLIGIBLE

6.4 Impact of GPS assistance on ARA hazards

6.4.1 It was found that the proposed GPS-assisted procedure would mitigate a number of weather radar-related hazards. In particular, GPS would be effective in:

- reducing the probability of approaching the wrong installation by providing an independent cross-check of the destination location from the navigation database;
- detecting major errors in the weather radar display, such as significant inaccuracies in the displayed position of the destination (and hence other obstacles);
- assisting the pilot in initiating and maintaining an accurate track (and, hence, heading) to the destination.

6.4.2 The introduction of GPS cross-checks reduces the probability of some of the ARA procedure conflict scenarios, with the overall result that one CS is changed from TOLERABLE to NEGLIGIBLE, and three CSs from UNACCEPTABLE to TOLERABLE.

6.5 Summary of recommendations

6.5.1 The analysis has identified the following recommendations:

- Handling and non-handling crew workload associated with the new procedure should be monitored initially to ensure that it does not, for any reason, significantly increase (see 2.4.5 and 2.4.6).
- The location of GPS reference points on installations should be standardised (see 2.3.27).
- Breaches of maximum allowable discrepancy between the GPS and weather radar range and/or bearing data should be recorded for further analysis (see 2.3.23 and 2.3.35).

6.5.2 It is recommended that flight crew training should address the following issues:

- Even when both GPS and weather radar sensors appear to be in agreement, there is a possibility that, either both sensors are malfunctioning, or that the helicopter is approaching a different installation from the one intended (see 4.1.7 footnote 3).
- Crews should be made aware of the fact that current GPS reference waypoints do not necessarily indicate the location of the helipad (as might be expected) (see 2.3.27).
- Crews should be made aware of the initial lack of confidence likely in the track and heading established under GPS guidance, and consideration should be given to conducting 'practice' ARAs in good weather to build up experience with the approach in benign conditions (see 2.5.1).

7 References

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