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CAA Contract No. 041/SRG/R&AD/1

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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 Shell Aircraft Limited. The work was instigated at Smiths Aerospace Electronic Systems - Southampton and carried out by Bristow Helicopters Limited in response to the conclusions and recommendations of earlier research performed for CAA and reported in CAA Paper 97005.

The CAA considers that the trial has been very successful in demonstrating real safety benefits, and that it has exceeded all expectations. A measure of its success is that the UK Industry has voluntarily elected to fully implement HOMP across all its North Sea helicopters in advance of any regulatory action. This initiative has been led by the UK oil industry (UK Offshore Operators Association - UKOOA), who are funding the programme through a levy on the helicopter hourly charter rates.

The CAA is continuing to promote HOMP by funding and otherwise supporting its extension to a second helicopter type (Sikorsky S76), and to a second helicopter operator (CHC Scotia Helicopters Limited at Aberdeen). This work is being co-ordinated with the industry-led full scale implementation and is designed to expedite and assist that process. Work on enhancing HOMP is also planned and will involve the addition of: a measure of low airspeed; pilot workload algorithms; facilities for mapping of helideck environments (turbulence and elevated temperatures); means of allocating severity values to ‘events’.

In addition, the CAA proposes to use this report to lobby ICAO for the extension of the recent amendment to Annex 6 Part 1 to Part 3 in respect of flight data recorder-equipped helicopters. The amendment effectively made flight data analysis programmes Recommended Practice for fixed wing aircraft over 20 tonnes from 1 January 2002, and a Standard for fixed wing aircraft over 27 tonnes from 1 January 2005.

Glossary of Terms

AGL	Above Ground Level
ARA	Airborne Radar Approach
ARINC	Aeronautical Radio Inc.
ASR	Air Safety Report
ATC	Air Traffic Control
BA	British Airways
BALPA	British Airline Pilots Association
BASIS	British Airways Safety Information System
BASIS FDM	BASIS Flight Data Measurements Module
BHAB	British Helicopter Advisory Board
BHL	Bristow Helicopters Limited
CAA	UK Civil Aviation Authority
CAADRP	Civil Aircraft Airworthiness Data Recording Programme
CAP	Civil Aviation Publication
CD-RW	Compact Disk – Read/Write
CQAR	Card Quick Access Recorder
CRM	Cockpit Resource Management
DAPU	Data Acquisition and Processing Unit
EGPWS	Enhanced Ground Proximity Warning System
EHM	Engine Health Monitoring
ES-S	Smiths Aerospace Electronic Systems - Southampton
FAA	Federal Aviation Administration
FAT	File Allocation Table
FDE	BASIS Flight Data Events module
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FDS	BASIS Flight Data Simulation module
FDT	BASIS Flight Data Trace module
FDV	BASIS Flight Data Viewer module
FOQA	Flight Operations Quality Assurance
FSO	Flight Safety Officer
GAIN	Global Aviation Information Network

GPS	Global Positioning System
HLL	Helideck Limitations List, previously known as the IVLL
HOMP	Helicopter Operations Monitoring Programme
HUMS	Health and Usage Monitoring System
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IHUMS	Integrated HUMS (i.e. HUMS+FDR)
IMC	Instrument Meteorological Conditions
IVLL	Installation and Vessel Limitation List
LAS	Low Airspeed
MDR	Maintenance Data Recorder
MOR	Mandatory Occurrence Report
MTOW	Maximum Take-Off Weight
Ng	Engine Gas Generator Speed
PCMCIA	Personal Computer Memory Card Interface Architecture
RMS	Root Mean Square
SESMA	Special Event Search and Master Analysis
SMS	Safety Management System
SOP	Standard Operating Procedure
UKOOA	UK Offshore Operators Association
VNE	Maximum Speed (Never to be Exceeded)
VNO	Maximum Speed Normal Operation

Executive Summary

This report presents the results of the Helicopter Operations Monitoring Programme (HOMP) trial. The objective of this trial was to demonstrate the use of Flight Data Monitoring (FDM) techniques in helicopter operations and to evaluate the benefits obtained.

FDM is "a systematic method of accessing, analysing and acting upon information obtained from digital flight data records of routine flight operations to improve safety." It is a well-established practice in many fixed wing airlines and has become an essential part of airline safety management processes with proven safety and other benefits. As a result, FDM for fixed wing aircraft is to be made an ICAO Recommended Practice from 2002 and a Standard from 2005.

With support and part funding from Shell Aircraft Limited, the CAA instigated a research project to trial a helicopter FDM programme, known as the HOMP. The programme was developed and directed by an integrated project team, with members from the CAA, Shell Aircraft, and the contractors. Using the Quick Access Recorders (QARs) and data replay and analysis system provided, the trial successfully demonstrated the routine downloading and pro-active analysis of flight data from five FDR equipped North Sea helicopters.

Comprehensive sets of flight data events and measurements were implemented to monitor the helicopter operations and an effective capability was achieved. The PCMCIA card based QARs used were very reliable and a total of approximately 11,500 hours of data was gathered, with an impressive data collection rate of 90-95%. Significant enhancements were made to the data replay and analysis software during the trial, which resulted in a very effective analysis tool, well matched to the requirements of the HOMP Operator.

The programme achieved excellent results. Significant safety issues were identified and the operator was able to take action to address them. The operator successfully implemented a closed-loop process for following up significant events, taking appropriate actions, and then monitoring the effectiveness of these actions. Aircrew responded positively to the programme and were receptive to any feedback provided. The large amount of new information produced by the trial enabled operational risks to be more accurately assessed.

The results obtained clearly demonstrated that the HOMP can bring about improvements in flying practice, training, operating procedures and coping with the operational environment. As a result of the success of the trial and the promulgation of the findings by the project team, UKOOA have committed their members to the implementation of HOMP on all FDR-equipped UK public transport helicopters operating over the UK Continental Shelf.

Section 1 Introduction

There is now widespread acceptance in the airline industry that Flight Data Monitoring (FDM) programmes improve safety, whilst providing a number of other operational and economic benefits. These programmes were pioneered in the UK by the Civil Aviation Authority (CAA) and British Airways, and monitor flight operations by routinely analysing aircraft flight data to detect deviations from normal, expected, or flight manual practice. They provide continuous operational quality control with timely feedback on sub-standard practices, and produce valuable information for the evaluation and improvement of operating procedures and the environment.

The CAA has also, for many years, been working to improve the safety of helicopters operating over the North Sea. Notable initiatives have included trials of Health and Usage Monitoring Systems (HUMS), introducing a mandatory requirement to fit Flight Data Recorders (FDRs), and mandating the fitting and use of HUMS. More recently the CAA instigated trials of an FDM programme for North Sea helicopters, known as the Helicopter Operations Monitoring Programme (HOMP), which represented the first application of FDM to helicopters. As the helicopters were already equipped with FDR systems, the HOMP represented a near term low risk, and low cost, opportunity to enhance operational safety by making pro-active use of the flight data which was already being acquired.

The HOMP trial was jointly funded by the CAA and Shell Aircraft Limited. Smiths Aerospace Electronic Systems – Southampton (ES-S, formerly Stewart Hughes Limited) was prime contractor to the CAA for the trial. The HOMP was operated by Bristow Helicopters Limited (BHL) and involved five Super Puma helicopters based at Aberdeen and Scatsta (in the Shetland Islands). The helicopters were equipped with BAE Systems PCMCIA Card Quick Access Recorders (CQARs) to extract and download the flight data. British Airways (BA) provided the helicopter flight data replay and analysis software, comprising four BASIS flight data modules. The HOMP trial consisted of an 8 month development phase followed by a 2 year operational phase.

This report presents the overall results of the trial. Section 2 introduces the concept of FDM, describes the significant safety and other benefits which have been achieved on fixed wing aircraft, and defines a generic FDM process which provides the model for the HOMP. The integration of an FDM programme into an operator's existing safety management system is also addressed. Section 3 introduces the HOMP and describes the trial programme. Section 4 presents a detailed description of the equipment utilised in the trial and the flight data analysis that was performed. Section 5 gives a detailed description of the HOMP trial operational experience. Sections 6 and 7 present the results obtained from the trial, focussing on the HOMP flight data event and measurement analysis respectively. Section 8 describes the HOMP processes and policy statement developed by the operator during the trial. Section 9 summarises the requirements for, and estimates the costs of, a full scale HOMP implementation. Finally, Section 10 presents the conclusions that have been drawn from the trial.

Section 2 FDM Background Information

2.1 FDM – A powerful safety tool with proven benefits

2.1.1 FDM concept

The world-wide commercial aviation fatal accident rate has not decreased significantly since 1980-85. The levelling of the accident rate curve suggests that the safety returns from "traditional" ways of improving safety (e.g. new technologies and systems, improved training, regulation, inspection and enforcement) are diminishing, and that it is necessary to find new ways of preventing accidents and incidents. Reference [1] states:

> "Why do aviation professionals who are highly trained, very competent, and proud of doing what they do well, still make inadvertent and potentially life-threatening mistakes? Blaming the problems on "human error", even if accurate, does little to prevent recurrences of the problem. The flattening of the accident rate curve tells us that the historic focus on the individual, while necessary, is no longer sufficient. Instead of focussing solely upon the operator, e.g. with more regulation, punishment, or training, it is time to start sharing information that can help improve the system in which the operator is operating."

One of the new (to the world-wide aviation community as a whole) ways the aviation industry has been adopting is the voluntary, proactive collection and use of information about aviation safety problems before they result in incidents or accidents. The collection of information can take two primary forms:

a) Voluntary, non-punitive incident and hazard reporting programmes (e.g. the raising of Air Safety Reports by aircrew.)

b) Flight Data Monitoring (FDM) programmes. Reference [2] defines FDM as "A systematic method of accessing, analysing and acting upon information obtained from digital flight data records of routine flight operations to improve safety."

NOTE: Whilst this report is focussed on (2), it must be appreciated that the above two forms of information collection are entirely complementary and both are required for effective safety management.

The power of this approach is explained below through the concepts of the "Heinrich pyramid" and the "light box" (Reference [1]):

The Heinrich pyramid

The Heinrich pyramid (Figure 2.1) postulates that for every major accident, there will be 3-5 less significant accidents, 7-10 incidents and at least several hundred unreported occurrences.

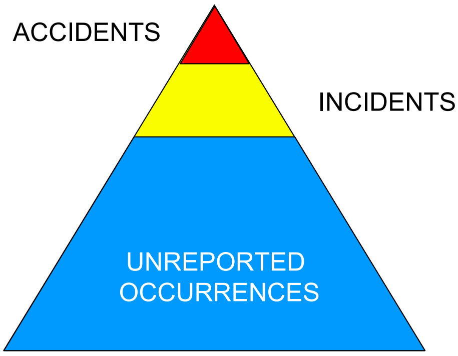


Figure 2.1 The Heinrich Pyramid

Usually these occurrences are not reported because, by themselves, they are innocuous, i.e. nobody was hurt and nothing was damaged. However, today's unreported occurrences are the "building blocks" of tomorrow's accidents and incidents; and when they coincide with the other building blocks from the "unreported occurrences" part of the pyramid, they may some day generate an incident or accident.

Obtaining information on what were previously unreported occurrences enables a pro-active approach to be taken to address operational risks before they result in incidents or accidents. Only if the risks are known can steps be taken to reduce them. No information means that no action can be taken.

The light box

Commercial aviation accidents are rare and random events and are analogous to light coming out of a box without any discernible pattern. The question is why does the light emerge in such a random fashion? Upon opening the box, it is discovered that it contains a series of spinning disks with holes, rotating about a common axis. The light emerges from the box (i.e. an accident occurs) if, and only if, the holes in all the disks happen to line up in front of the light (Figure 2.2).

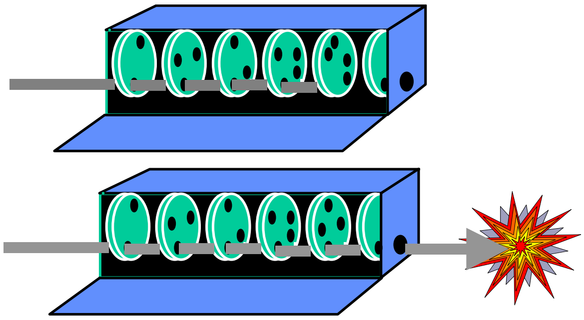


Figure 2.2 The Light Box

Each spinning disk could be compared to a link in the chain of events leading to an accident. A study by Boeing (referred to in Reference [1]), has revealed accident chains with as many as twenty links, each one representing an event that, with a different outcome, would have broken the chain and avoided the accident. Every one of these links, separately, is usually innocuous and resides in the "unreported occurrences" part of the Heinrich pyramid, but when they happen to combine in just the wrong way (i.e. when the holes in the spinning wheels happen to line up), the result is an accident.

Viewed in this way, the objective of proactively collecting and acting on information to prevent accidents is to obtain information about each spinning wheel (each link in the chain) separately, in order to try to reduce the number of holes in each wheel (i.e. operational risks). This effectively dissects a potential incident or accident into its component parts, facilitating a separate remedy for each component part of the problem.

2.1.1.1 Non-aviation parallels

The same concept of using information proactively to prevent accidents is being developed in areas other than aviation, for example health care and information infrastructure security (Reference [1]).

In health care the Committee on Quality of Health Care in America, created by the US Institute of Medicine, recently issued a report entitled "To Err is Human: Building a Safer Health System." It reflects concern that as many as 90,000 people a year die from medical mistakes, and proposes a system to systematically collect and analyse information about near-miss mistakes in order to learn more about how to prevent mistakes that could kill or injure. The premise of the system is described as follows:

> "Preventing errors means designing the health care system at all levels to make it safer. Building safety into processes of care is a much more effective way to reduce errors than blaming individuals…. The focus must shift from blaming individuals for past errors to a focus on preventing future errors by designing safety into the system. When an error occurs, blaming an individual does little to make the system safer and prevent someone else from committing the same error."

Similarly, in Presidential Decision Directive 63 issued in 1998, the US President expressed concern about the vulnerability of the nation's information infrastructures to computer "hackers" and terrorists. Accordingly, the Critical Infrastructure Assurance Office (CIAO) was created to develop means of improving the security of such infrastructures. In order to learn more about the weaknesses of the various information infrastructures and how to remedy those weaknesses, the CIAO plans to develop a system to collect information systematically about near-breaches of information security - exactly the same process that the aviation and medical communities are developing.

2.1.1.2 FDM programmes

The objective of FDM programmes is to enable proactive safety intervention based on analysis of exceedances and trends in flight data obtained on a routine basis from line operations. FDM programmes are owned and operated by the airlines. Such programmes are powerful pro-active tools for enhancing flight operational safety standards. They improve safety by continuously monitoring operations, detecting adverse trends in operational behaviour, and detecting weaknesses in crews, the aircraft, at certain airports or in Air Traffic Control (ATC).

An FDM programme can involve up to four types of data, which are defined in Reference [2] as:

a) Event data. This is the traditional approach to FDM that looks for exceedances of trigger levels which indicate deviations from flight manual limits, standard operating procedures or good airmanship.

b) Routine measurements. Increasingly, data is retained from all flights and not just those producing events. The reason for this is to monitor for more subtle trends and tendencies before the trigger levels are reached. A selection of measures are retained that are sufficient to characterise each flight and allow comparative analysis of a wide range of aspects of operational variability.

c) Incident investigation. FDR data should be used as part of the follow-up of Mandatory Occurrence Reports (MORs) and other reports. FDR data obtained for use in this way falls under the mandatory requirements of JAR OPS.

NOTE: MORs are reports that are required to be issued to the CAA to ensure that it is advised of hazardous or potential hazardous occurrences, and that relevant information is disseminated to other organisations. MORs differ from Air Safety Reports as the latter are part of an organisation’s internal safety reporting processes.

d) Engineering data. Both measurement and event data can be used to assist the engineering function. Traditionally, engine monitoring programs have looked for measures of engine performance to deduce efficiency and predict the approach of failures. These programs are normally supplied by the engine manufacturer and feed their own databases. By imaginative use of the many engineering measurements available, a broader picture of the aircraft's systems can similarly be achieved.

2.1.2 FDM benefits on fixed wing aircraft

Experience has shown that proactive use of information from an FDM programme not only improves safety, but can also result in savings in operations and maintenance.

Reference [3] groups the benefits from FDM into four areas; the identification of:

a) Non-compliance and divergence from Standard Operating Procedures (SOPs). This is probably the most critical and useful part of FDM and is a continuous audit of pilot performance.

b) Inadequate SOPs and inadequate published procedures. If pilots do not consistently comply with SOPs it is perhaps sensible to consider first whether the SOPs could be improved.

c) Ineffective training and briefing, and inadequate handling or command skills. It is relatively straightforward to use FDM to assess the effectiveness of training, communication with crew and briefing systems.

d) Fuel inefficiencies and environmental infringements. Statistical analysis of route fuel and taxi fuel assists in refining flight planning. FDM is also used to identify non-compliance with noise procedures.

FDM data can also used for two other purposes (Reference [3]):

a) Engine health monitoring (EHM): The objective of EHM is to eliminate unscheduled engine removal through unexpected deterioration or failure, and to ensure optimum performance (e.g. through Variable Inlet Guide Vane scheduling). As well as precipitating timely removal it can also provide objective data following an incident that may enable an engine to be left on-wing until a more convenient time.

b) Monitoring of aircraft performance and system serviceability: This covers a variety of areas, e.g.

- Validating aircraft performance against the manufacturer's specification.

- Comparing fuel burn across a fleet to identify aerodynamic inefficiencies that may be caused by inexact door alignment or control rigging.
- Compiling statistical data from analysis of all autolands to ensure no degradation after certification.
- Use for diagnostics and to resolve design and maintenance problems, for example, wheel and brake reports.
- Collating data to support cases for change (e.g. runway resurfacing) and development (e.g. EGPWS).
- Regular checking of FDR parameters to maintain the serviceability of the FDR system for accident/incident investigation.

The primary benefits from FDM programmes are undoubtedly safety related. Scandia Insurance has overlaid FAA data with that on non-USA airlines (Figure 2.3). This shows that airlines which have been using FDM data for 7-14 years now have a lower accident rate than US airlines, and those airlines which have used FDM for more than 14 years have an accident rate under half that experienced by the US carriers.

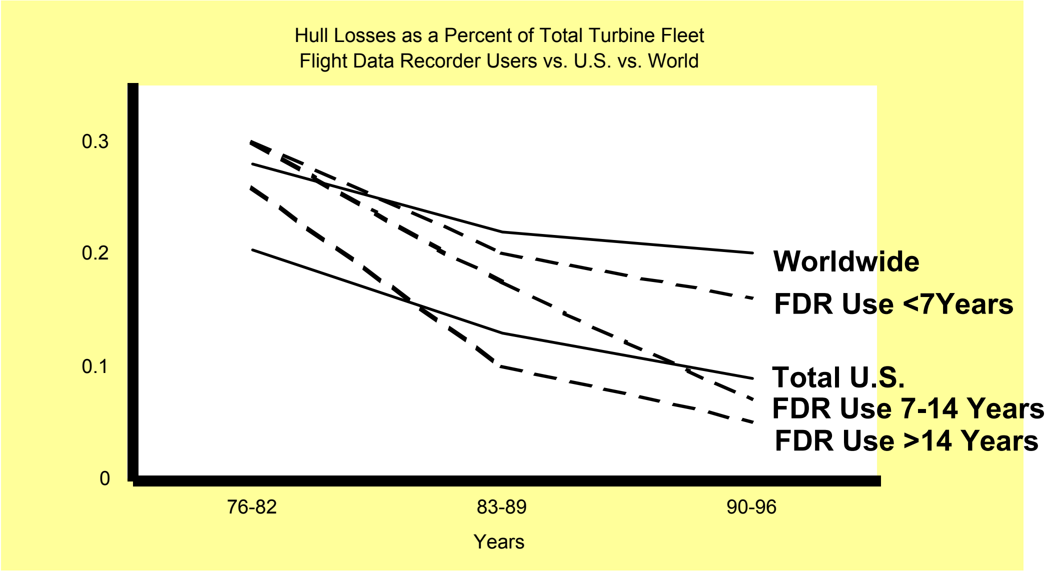


Figure 2.3 Safety Benefits of FDM

2.1.2.1 Cost benefits

Reference [4] identifies cost savings through the prevention of a catastrophic accident. Accident costs include the following:

- Compensation costs for loss of life
- Loss of cargo, baggage, mail
- Third party damage costs
- Hull replacement cost
- Cost of bringing a replacement aircraft up to the fleet standard
- Costs associated with resulting actions such as grounding of a fleet
- Other accident related costs, e.g. setting up an emergency centre

- Loss of revenue due to loss of an aircraft
- Loss of revenue likely through lowering of public confidence
- Reduction in company value due to stock market loss of confidence

Offsetting the above is the insurance payment for the loss, however this generally only covers the first three items and some element of the fourth. There would be additional industry costs that would not fall upon the individual airline resulting from any disruption caused by an accident, or a general loss of confidence in aviation and increased overall risk levels.

Perhaps more relevant to preventative programmes such as FDM is the cost of incidents such as tail scrapes, heavy landings, turbulence upsets etc. The costs associated with these more common events are easier to estimate. Typical common incident cost factors may be:

- Operational: flight delays, flight cancellations, runway obstruction, alternate passenger transportation, passenger accommodation, passenger complaints, catering, loss of revenue, ferry flight, crew change, training/instruction, loss of reputation.
- Technical: aircraft recovery, aircraft repair, test flight, incident investigation, technical documentation, spare parts, technical inventory, aircraft on ground, lease of technical facilities, repair team accommodation, training/instruction, re-certification.

Other potential benefits and cost savings include (Reference [4]):

- Insurance savings - based on experience of long term FDM airlines
- Engine savings - postponed/reduced removals, records of use of derate
- Fuel savings - trim analysis, airframe deficiencies
- Fuel tankering - more accurate fuel burn calculations
- Brake savings - better crew awareness and highlighting heavy use
- Flap maintenance savings - fewer overspeeds and use as a "drag flap"
- Inspections savings - reduced number required due to the availability of measurements for heavy landings, engine over temp', flap placard etc.
- Increased aircraft availability - better/faster fault diagnosis
- Increased simulator effectiveness - better targeted
- ETOPS monitoring - automatic rather than manual
- Warranty support - definitive usage evidence
- Autoland support - record keeping and system health/accuracy

2.1.3 Support for FDM

A number of statements have been made by key personnel in influential organisations expressing strong support for FDM:

a) “The CAA strongly encourages the adoption of such (FDM) programmes as a key part of operator Safety Management Systems (SMS). It is the CAA's intention to work with industry to further improve aviation safety by using FDM methods and information to enhance safety through knowledge.” David Wright, Senior FDR Analyst, CAA Safety Regulation Group. Royal Aeronautical Society Conference paper, March 2000.

b) "Such systems allow an airline to identify and address specific operational risks and are strongly encouraged as part of a Safety Management System". Peter Hunt, Head of the Operating Standards Division of the UK CAA Safety Regulation Group - Industry Safety Conference, March 1999.

c) "Because of its capacity to provide early objective identification of safety shortcomings, the routine analysis of digital flight data offers significant additional potential for accident avoidance". "It is potentially the best safety tool of the 21st Century." Hon Jane F Garvey, FAA Administrator - FOQA Policy Statement (4910-13), December 1998.

d) "It is the most important way to dramatically improve flight safety." Captain Lowe, President Royal Aeronautical Society - The Aerospace Professional, February 1999.

e) "Knowledge of risk is the key to flight safety. Until recently that knowledge had been almost entirely confined to that gained retrospectively from the study of accidents and serious incidents. A far better system, involving a diagnostic, preventive approach, has been available since the mid-1970s." Editorial, Flight International, December 1998.

2.1.3.1 ICAO State letter AN6/1.2-00/4

ICAO State letter AN6/1.2-00/4 presented recommendations from the Accident Investigation and Prevention (AIG) divisional meeting in 1999 for amendment of Annex 6 of the ICAO recommendations for standards and recommended practices. The following amendments were fully supported by the UK:

> 3.6.2 "From 1 January 2002, an operator of an aeroplane of a maximum certified take-off weight in excess of 20,000 kg *should* establish and maintain a flight data analysis programme as part of its accident prevention and flight safety programme."
>
> 3.6.3 "From 1 January 2005, an operator of an aeroplane of a maximum certified take-off weight in excess of 27,000 kg *shall* establish and maintain a flight data analysis programme as part of its accident prevention and flight safety programme."
>
> 3.6.4 "A flight data analysis programme *shall* be non-punitive and contain adequate safeguards to protect the source(s) of the data."

The above amendments effectively mandate FDM on aircraft above 27 tonnes MTOW from 2005. In their response to the ICAO State letter, the UK made the following comment on the future development of FDM programmes:

> "The UK believes that a flight data analysis programme should be implemented within the accident prevention and flight safety programme of all operators of helicopters having type 4 or 4A recorders. The UK believe such programmes are demonstrably practical, at least on helicopters already having suitable crash protected flight recorders and associated systems. Initial results from a UK trial indicate this is as practicable on helicopters as on fixed wing and shows significant safety benefits."

2.2 The FDM process

2.2.1 The "closed loop" FDM process

The objective of FDM systems is to enable an airline to identify, quantify, assess and address operational risks. The FDM "closed loop" process (References [2] and [4]) is described below and illustrated in Figure 2.4:

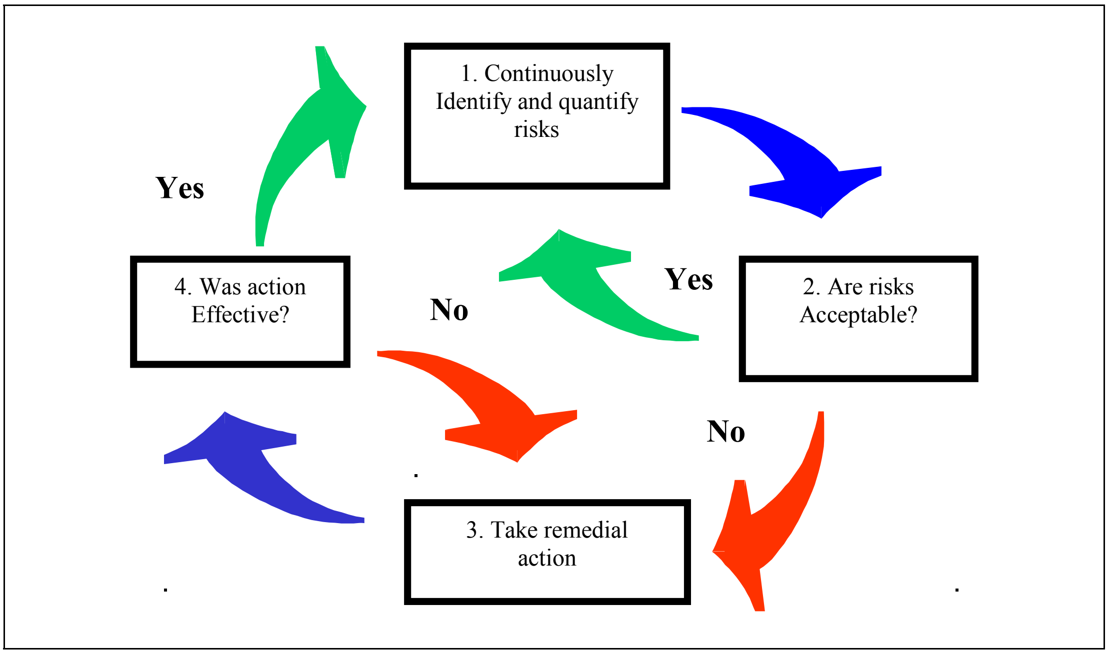


Figure 2.4 The "Closed Loop" FDM Process

1 **Continuously identify and quantify operational risks.** Identify areas of risk and measure current safety margins - this will establish a baseline operational metric against which to detect and measure any change. Then identify and quantify changing operational risks. In addition to highlighting changes from the baseline the system should enable the user to determine when non-standard, unusual or basically unsafe circumstances occur in operations.

2 **Are risks acceptable?** Formally assess the risks to determine which are not acceptable. Information on the frequency of occurrence, along with estimations of the level of risk present, is then used to determine whether the level of risk associated with an individual occurrence or occurrence trend is acceptable. Primarily, the system should be used to deduce whether there is a trend towards unacceptable risk prior to it reaching risk levels which would indicate that the safety management process has failed.

3 **Take remedial action.** Where risks are not acceptable, instigate remedial activity. Once an unacceptable risk, either actually present or predicted by trending, has been identified then the appropriate risk mitigation techniques must be used to define and instigate remedial actions.

4 **Was action effective?** Measure the effectiveness of action and continue to monitor risks. Once remedial action has been taken it is critical that its effectiveness is confirmed, i.e. in reducing the original identified risk without increasing risk elsewhere. When no adverse safety impact is identified, re-establish the baseline operational metric to measure future changes.

The FDM process must be recognised as one which is founded on a bond of trust between the operator, its flight crews and the regulatory authority. The process must actively demonstrate a non-punitive, non-disciplinary policy. The focus has to be on providing positive feedback to improve all elements of the system. This typically creates a need for:

- Confidentiality, with the identity of individual flight crew being protected by tightly controlled access to data, data de-identification procedures and restricted contact with flight crew (often through the Pilot Association).
- Written agreements between flight crew and management on issues such as the aims and objectives of the FDM programme, restrictions on access to data and contact with crews, and how information generated by the process can be used.

Detailed information on all the components of the FDM process can be found in References [4] and [5].

2.2.2 A practical implementation of the FDM process

Figure 2.5 shows the components of a typical operator's FDM process. This is based on the process currently followed by BA.

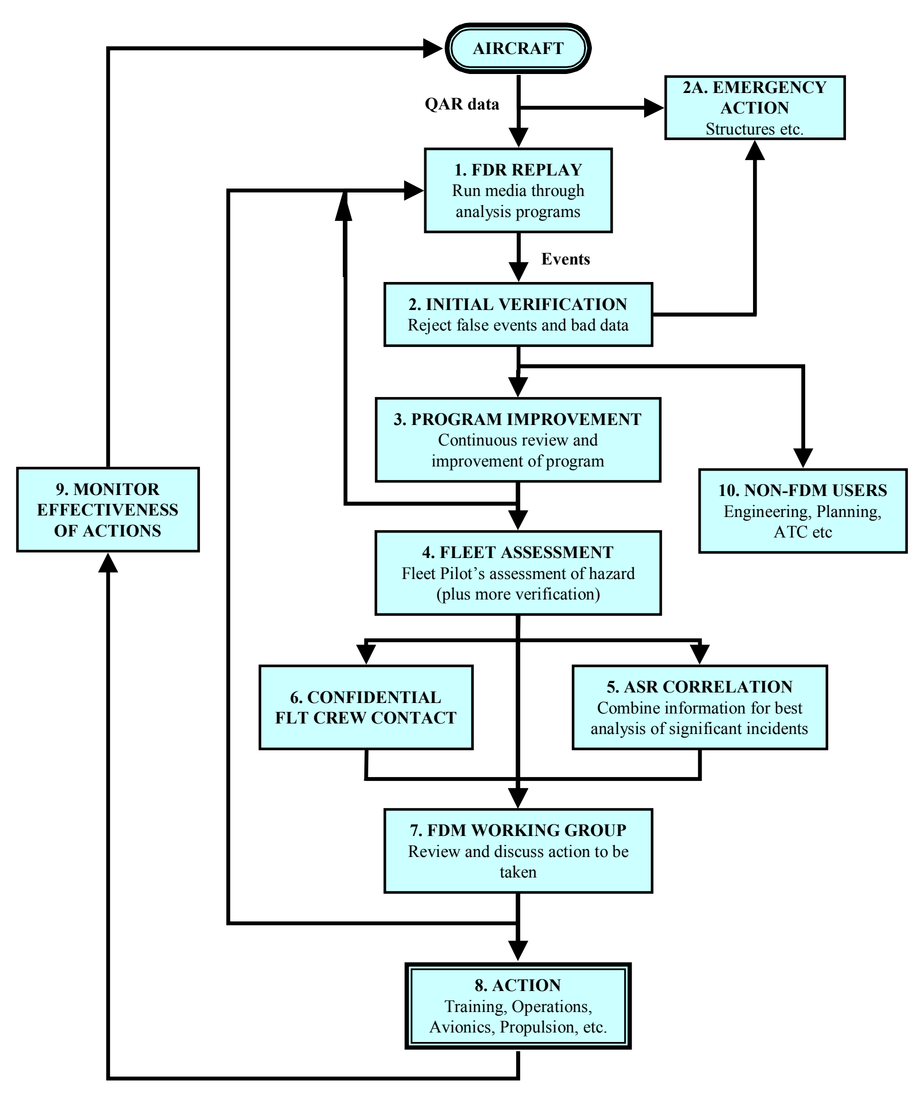


Figure 2.5 Typical FDM event process

1 **FDR replay** Aircraft QAR data is downloaded and replayed through the FDM data replay and analysis program.

2 **Initial Verification** This confirms that any events generated are valid and not caused by 'bad data' due to sensor problems etc. Initial examination of the results should be carried out as soon as possible after data replay so that, in exceptional circumstances, step 2A may be triggered.

2A **Emergency Action** Where the program identifies the need for immediate safety action, for example a very heavy landing with potential structural damage that has not been highlighted by other means, then relevant checks are instigated.

3 **Program Improvement** The process should include a continuous review of the information being generated to identify required improvements to the data replay and analysis program, for example the refinement of event definitions to eliminate 'false events'.

4 **Fleet Assessment** The events should be grouped by aircraft fleet and examined in detail by a selected, experienced pilot on each type. These use their knowledge of each aircraft and the associated operating environment to assess the events. Safety issues will be identified and initial actions decided upon.

5 **Air Safety Report Correlation** Where there is a more significant event, there is likely to be an ASR. Normally an interpreted summary of the FDR data will be added to the ASR investigation file and the follow-up controlled by the normal flight safety process within the airline's safety management system. If an event is deemed to be significant and no ASR is found to exist then, as part of item 6, flight crew can be prompted to raise one. Improvements in the consistency of raising and processing of ASRs can be expected as a by-product of FDM.

6 **Confidential Flight Crew Contact** A Pilot Association representative may be requested to speak informally with the flight crew concerned to find out more about the circumstances of an event. If deficiencies in pilot handling technique are evident then the informal approach, entirely remote from management involvement, usually results in the pilot self-correcting any deficiencies. If any re-training is found to be necessary, this should be carried out discreetly.

7 **FDM Working Group** This would typically meet on a monthly basis to assess both significant individual events and any undesirable trends in event statistics. Events should be assessed in the context of previous experience to determine whether they are indicative of a trend or are unique. The assessment should identify the degree of direct or indirect hazard associated with individual events or event trends. This will enable resources to be targeted at the most beneficial reduction in hazard, which may be to prevent a large number of relatively low risk events or to eliminate a low number of high risk events. The output from this step in the process should be recommendations on any appropriate actions to minimise hazards and prevent the re-occurrence of significant events.

8 **Action** Taking action to address identified hazards is the ultimate goal of the whole process. In addition to specific changes in SOPs and training, typical actions should include raising general awareness of identified hazards and providing reminders of SOPs through the issuing of safety bulletins or providing feedback through crew newsletters. All actions arising from the FDM process should be recorded to provide an audit trail.

9 **Monitor Effectiveness of Actions** After taking action, the final stage in the closed loop FDM process is to monitor the effect of actions to check that these have reduced identified risks and to ensure no risks are transferred elsewhere.

10 **Non-FDM Users** Information processed by the FDM and associated software may also be used by other areas of the airline, e.g. engine health monitoring, planning or ATC services.

2.3 Integrating FDM into the existing safety management system

FDM should ideally become an integral part of an operator's existing safety management system. Reference [4] states:

> "An FDM programme held remote from all other safety systems within an airline will have reduced benefits compared with one that is linked with other safety monitoring systems. This other information gives context to the FDR data which will in turn provide quantitative information to support investigations that otherwise would be based on less reliable subjective reports. FDM, Air Safety Reporting, Technical and Engineering Reporting, Ground Incidents, Design and finally Human Factor Reporting systems must be linked together to produce a best estimate of operational risks. Where necessary these links may have to be configured to restrict data identification while passing useful information."

FDM is a closed-loop process which allows an operator to identify, quantify, assess and address operational risks, then monitor changes brought about by remedial action. An operator's existing safety management system can provide the organisational structure and mechanism for this closed-loop process, and also provides access to complimentary information on operational risks.

Figure 2.6, extracted from Reference [6], shows the three business pre-requisites for systematic safety management.

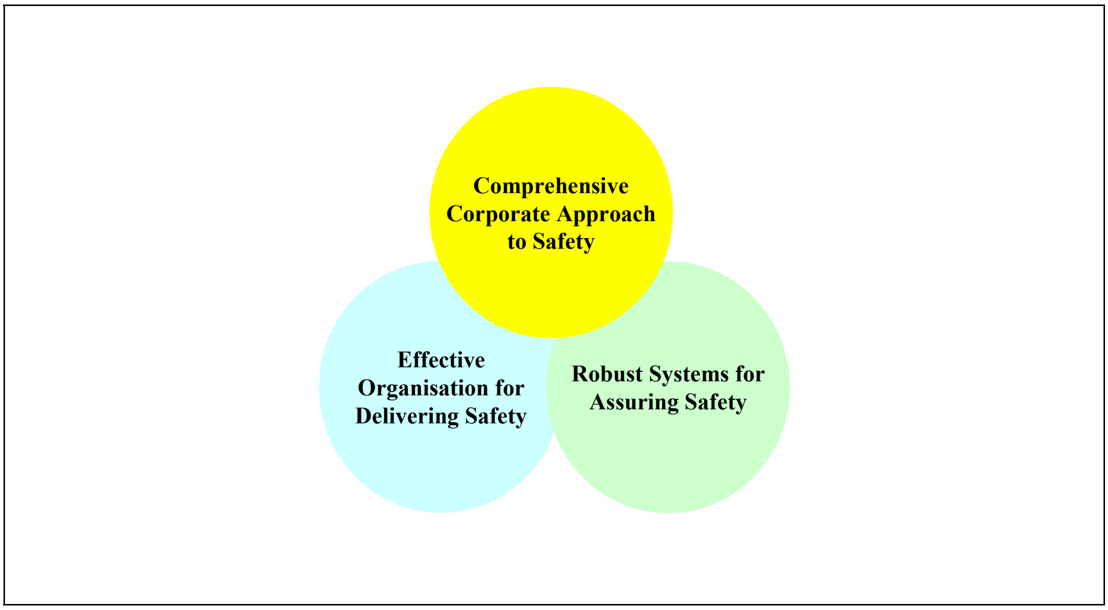


Figure 2.6 Pre-requisites for Successful Safety Management

The business elements shown in the figure provide the following:

Corporate Approach

- Establishes and leads an effective corporate safety culture
- Visible senior management leadership and commitment
- Sound safety policy
- High, well understood, safety standards
- Realistic safety targets and objectives
- Effective motivation and communication

Effective Organisation

- Clearly defined responsibilities/accountabilities for safety
- Effective safety training
- High levels of competency in safety
- Comprehensive planning, procedures and documentation
- Competent safety advisors

Robust Systems

- Systematic hazards and effects management process
- Techniques for measuring safety
- Thorough incident investigation and follow-up
- Audit of safety standards and practices
- Application of Quality Assurance principles throughout

FDM represents a powerful additional "robust system" for measuring safety, which should benefit from the "effective organisation" already provided for safety management. The following section presents information from Reference [7] on the benefits of integrating FDM into an operator's existing safety management system.

2.3.1 The benefits FDM can provide to existing safety systems

Because of its repeatable and independent nature, FDM event detection and measurement analysis lends itself well to the active monitoring and audit functions needed to give safety assurance, and is more effective than traditional means of audit or inspection. Periodic audits such as check flights do not provide visibility of the risks encountered during routine operations. In monitoring all flights, FDM can help to fill in this missing information and assist in the definition of what is normal practice. This gives assurance that the safety process is managing actual rather than perceived safety issues.

Current occurrence reporting systems have a very restricted view of the total operation, whereas FDM gives a depth of information beyond accidents and incidents that indicates the underlying risk patterns. FDM can be used to extend the knowledge of issues raised by reporting systems and also extend this to areas where little information exists.

FDM provides a continuous monitoring function which allows the identification of risk trends. This enables measures to be put in place to ensure that the level of safety is at least being maintained or preferably improved. In addition, by providing information on more frequently occurring lower risk events as well as high risk events, FDM allows the identification of potential as well as actual hazards. The frequencies of lower risk events can be fed into a risk model to investigate the overall probability of a combination of multiple events leading to a significant hazard.

FDM information can greatly enhance the investigation of reports such as ASRs and MORs. The quantitative data allows a fuller understanding of the circumstances surrounding an incident and can provide information on factors such as pilot technique, handling difficulties, turbulence, structural limit exceedances etc. Because of its independent nature, FDM can also help to encourage good safety reporting. For example, FDM may occasionally detect a hazard for which no ASR was submitted. In this case the persons involved can be encouraged, through confidential contact by a crew representative or other trusted person, to submit a report. This method of contact has proved to be very effective in soliciting reports and a good means of imparting constructive safety advice to those involved.

The act of setting up an FDM programme requires the operator to define the normal operation and the bounds of acceptability. This process provides a useful insight into standards and can in itself highlight potential conflicts or unclear areas within current operating procedures. Similarly FDM information can be utilised in the initial assessment of risk levels when setting up a new safety management system. These can be tested against the specified standards to determine if safety levels are acceptable.

2.3.2 The benefits existing safety systems can provide to FDM

Owing to the way in which FDM has evolved, supporting processes have, in some cases, tended to be rather ad-hoc, locally implemented, and controlled by informal procedures. However, the “closed loop” safety assurance processes required for an FDM programme are very similar to those implemented as part of existing safety systems. Knowledge of an actual or potential hazard must lead to a safety assessment and, where necessary, remedial action. Further, where action is taken some record of this must be kept to provide an audit trail. The existing safety systems can provide an organisational structure and systematic methodology for assessing and acting upon identified hazards to manage safety. Therefore, to obtain the maximum benefits from FDM, the programme needs to be integrated with existing safety systems, with common safety assessment and action processes and procedures.

FDM can only identify certain operational risks, and a complementary non-punitive reporting system (e.g. ASRs) is needed to provide a comprehensive picture of all the operational risks. Integrating the quantitative information from FDM with the contextual and qualitative information from ASRs allows a much better understanding of safety issues raised from both systems. The reports generated automatically from FDM programmes must be treated confidentially, however where an ASR has already been submitted, then relevant FDM events can be used to add to the understanding of the circumstances of the occurrence.

The existing safety systems can provide a standard route for bringing hazards identified from FDM information to the attention of other operators, Air Traffic Services, aircraft or equipment manufacturers, or the Regulator. FDM information on significant risk bearing events can follow the same route as existing safety reports. In the UK the accepted medium for broadcast is the Mandatory Occurrence Reporting Scheme. In addition, when it is an integral part of an organisation’s safety systems, FDM information can be used to provide regulatory assurance and the regulatory bodies can give credit for the proactive approach to safety being taken by the operator.

2.4 Some lessons from fixed wing FDM experience

There is a recognised need for guidance material to help operators to maximise the benefits of FDM and avoid some of the pitfalls which can result in difficulties or a loss of benefit. This section briefly summaries some lessons learned from fixed wing FDM experience.

2.4.1 FDM implementation

An FDM programme will be most successful if senior management have created a good safety culture within an organisation.

Planning an FDM implementation should start at the top with an overview, but must also address detailed issues. Overlooking details such as data extraction and replay system requirements will result in problems.

It is important that the objectives of, and procedures for, an FDM programme are defined in a protocol which is accepted by aircrew before FDM is implemented. Agreements must be reached with aircrew, and there must be a good consensus between all parties if a programme is to succeed.

An FDM programme must be seen to be non-punitive, and operated in a manner which ensures the trust and co-operation of aircrew. Trust will be lost and the programme could fail if FDM data is misused.

Different operators have taken different approaches to the positioning of FDM within their organisation, and to the interface between the programme and the Flight Safety Officer (FSO). Although there are advantages and disadvantages of different approaches, there is no single "best solution" and the approach taken must be tailored to the particular operator's size and organisational structure.

FDM programmes must be properly resourced. Some operators have failed to successfully implement FDM because they did not provide adequate resources to operate and manage the programme.

There is a need to appreciate the limitations of FDM information. It can only identify certain risk areas, and must be combined with information from other reporting systems to provide an adequate picture of overall risks.

Some FDM implementations have started as "hobby systems", have not been well integrated into the operator's organisation, and are highly dependent on the skills and motivation of a specific individual. It is important that a systematic approach to FDM implementation is taken to prevent this from occurring.

2.4.2 FDM process

It is difficult or impossible to maintain aircrew anonymity in small airlines. Where this is the case it is vital that the person following up events (e.g. the FSO) maintains independence, has the right personality for the task, and is trusted and respected by aircrew.

It is very important to obtain crew feedback when investigating significant events, otherwise the investigator can make wrong assumptions and come to an incorrect conclusion.

Different mechanisms have been used to contact crew when feedback is required for the investigation of significant events. In some cases this is done via a pilot association representative, in others information is sent in a sealed envelope. The mechanism used should be tailored to the requirements of the particular operator. If feedback is required, both crew should be contacted, not just the pilot or co-pilot.

It is important to communicate the outcomes of FDM programmes to all parties, lack of communication will erode support for the programme, and diminish the benefits.

2.4.3 FDM equipment

Careful selection of data recorder, recording medium and replay facility is very important. The reliability of recorders and recording media will affect the data capture rate and hence programme effectiveness. With current technology, use of a Quick Access Recorder is the preferred method of obtaining data from the aircraft. Downloading data from the crash protected memory of digital FDRs is more difficult and time consuming, and use of tape-based FDRs is too unreliable. The replay facility needs to be designed to cope with the expected throughput in order to avoid data processing bottlenecks.

Some operators have experienced an unacceptable rate of loss or damage of data recording media. As a result, one operator has adopted a systematic approach to media control, involving the transport of media in sealed boxes marked with a bar code for tracking purposes.

To ensure FDM systems are accepted, every effort must be taken to minimise the sources of data errors and to eliminate false event detections.

There would be some benefit from standardising event parameters and detection criteria to aid the sharing of lessons learned between operators.

Some operators have underestimated the technical expertise required to manage and support an FDM system.

FDM systems will continue to evolve and software upgrades can cause disruption if not managed properly.

It is important to provide a secure environment for the FDM data analysis system, with appropriate access restrictions.

Section 3 The HOMP Trial

3.1 Background to the HOMP trial

The history of FDM can be traced back to the beginning of one of the CAA's longest running safety research projects: the Civil Aircraft Airworthiness Data Recording Programme (CAADRP). This programme is managed by the Safety Analysis Unit within the CAA's Safety Regulation Group and has its origins in the early 1960s when ultra-violet paper flight data recorders were used to gather data from the jet transports then entering service. This led to the development of the Special Event Search and Master Analysis (SESMA) program – the first ever FDM system. For the last 30 years the CAA has been working in close co-operation with UK operators such as British Airways on the development and implementation of FDM.

For many years the CAA has also been working to improve the safety of the public transport helicopters operating over the North Sea in support of the oil and gas industry. It initiated trials of the first helicopter Health and Usage Monitoring Systems (HUMS) in the late 1980s, and introduced a mandatory requirement to fit Flight Data Recorders (FDRs) in the early 1990s. The CAA actively encouraged the fitting of HUMS to the North Sea helicopter fleet in the form of integrated HUM/FDR systems and, in 1999, mandated these systems for UK transport helicopters carrying more than 9 passengers.

With the support of Shell Aircraft Limited, the CAA initiated a project which brought together the above two initiatives to extend the scope of FDM beyond the current fixed-wing implementation and carry out a trial implementation of FDM on helicopter operations. In late 1998, following the successful completion of an initial feasibility study (see Section 3.2), the CAA instigated trials of an FDM programme for North Sea helicopters, known as the Helicopter Operations Monitoring Programme (HOMP). The HOMP trial represented the first application of FDM to helicopters. The following factors provide a justification for this initiative:

- FDM is now a well established practice amongst fixed wing operators, with demonstrated safety and other benefits (see Section 2). Airlines such as BA have clearly proven the benefits of FDM and are convinced that these programmes make a difference to their safety performance. BA's FDM programme, known as SESMA, is an essential part of the airline's safety management programme and is welcomed by aircrew, BALPA and management alike.
- The introduction of helicopter HUM systems has reduced the rate of occurrence of helicopter accidents due to technical causes by providing better information on the integrity of the helicopter powertrain. However, accidents are also caused by operational factors, and there is clear scope for further improving helicopter safety by providing better information on operational risks. This is particularly true for operations to/from offshore installations in the North Sea, which involve some unique difficulties.
- The basic requirement for a helicopter FDM programme – the availability of a flight data acquisition and recording system – has already been met. Therefore the implementation of a helicopter FDM programme is potentially a low risk and low cost opportunity to further improve helicopter safety.

3.2 HOMP feasibility study

The HOMP trial was preceded by a two phase feasibility study carried out for the CAA by Stewart Hughes Limited (now ES-S), working in co-operation with BHL.

The first phase was an initial feasibility study (Reference [8]). This involved analysing a historical database of FDR data recorded over a period of one year from one BHL Super Puma helicopter. A prototype set of helicopter operational events was generated and the data was analysed using the Polish company ATM Awionika's Flight Data Service (FDS) system, loaned to SHL by the CAA. The study was able to demonstrate some of the potential benefits which could be achieved from a HOMP.

The second phase of the work was a HOMP implementation study (Reference [9]). This involved consultations with all the UK-based North Sea helicopter operators to obtain their views on, and concerns about, a HOMP. In addition, the lessons learned from BA's FDM experience were analysed. A review of the available tools and equipment for a HOMP was carried out and recommendations were produced for a programme implementation.

The two phase study provided a clear justification for progressing the implementation of a HOMP, but identified a number of operator concerns and issues which ought to be addressed prior to any full scale implementation. There was a general perception that it would be more difficult to effectively monitor the operation of such a flexible air vehicle as a helicopter (in contrast to fixed wing aircraft which have clearly defined flight profiles), and that more effort may be required to interpret monitoring results. In addition, it was not known whether helicopter operations could be monitored in a way which would provide meaningful safety benefits. There was also widespread concern over the possible workload involved in managing a HOMP, including the handling of data from, and providing feedback to, remote operating bases. Other issues included the need to obtain the support of both the operator's management and flight crew for a HOMP programme, and any possible implications for commercial relationships between the operators and their customers, the oil companies. There are differences between the management, aircrew and customer relationships in a typical helicopter operator and those in a large scheduled airline such as BA. It was not known what potential impact these differences might have.

It was concluded that these concerns and issues could best be addressed by performing a HOMP trial on a limited number of aircraft. The objectives of this trial would be to:

a) establish how best to monitor helicopter flight operations.

b) evaluate the safety benefits of this monitoring.

c) evaluate the tools and equipment required for a HOMP and eliminate any technical risks associated with these.

d) establish and evaluate a programme management strategy.

e) determine the workload a HOMP would impose on a typical helicopter operator.

f) establish agreements between aircrew and management to ensure that the identity of aircrew is protected, and the focus is on positive feedback.

g) further expose industry to the concept of a HOMP, enabling a more informed consideration of its full scale implementation.

3.3 Review of helicopter operational accidents and occurrences

A review of helicopter operational accidents and occurrences was carried out based on information contained in the CAA Safety Data Department's UK Occurrence Reporting System (Reference [10]). The review provided an indication of the safety benefit which might be obtained from a HOMP and identified relevant flight data 'events' which could provide information for the prevention of a re-occurrence of previous incidents and accidents.

A statistical analysis of the operational accidents and occurrences showed that if the accidents and occurrences were separated, very different numerical distributions were obtained when these were categorised according to cause. Whilst the greatest number of occurrences were associated with the environment in which the aircraft operates, the analysis indicated that accidents were largely associated with aircraft handling. This was, in fact, an oversimplification of the situation. Many accidents had more than one causal factor and there were environmental factors present in a number of the accidents which were included in an aircraft handling classification.

A HOMP should be able to have a direct impact on the aircraft handling factors in accidents, and therefore should give a worthwhile safety benefit. In addition, whilst it may not be able to have a direct impact on the operating environment, a HOMP should provide better information on it, which would enable the setting of better operational limitations. A more detailed analysis of individual operational accident and occurrence records indicated that a HOMP has relevance to a significant percentage of previous UK accidents and fatal accidents.

The analysis provided an input to the HOMP event specification process to help ensure that events were targeted at relevant safety issues (the events are listed in Section 4.4). A number of accidents and occurrences were linked to offshore helideck environmental problems such as severe structure induced turbulence, rolling and pitching helidecks, the close proximity of obstacles, and hot gas exhausts from turbines and flare stacks. Others were linked to problems associated with aircraft handling and pilot disorientation such as a misjudged landing, disorientation on take-off, controlled flight into terrain and water, entry into a 'vortex ring' state, and roll over during taxiing. Further accidents and occurrences were associated with aircraft management problems such as a lack of fuel and landing with the wheels up.

3.4 HOMP trial

The HOMP trial was jointly funded by the CAA and Shell Aircraft Limited, and included the following participants:

- Smiths Aerospace Electronic Systems – Southampton, the prime contractor to the CAA for the trial.
- Bristow Helicopters Limited, providing the helicopters and operating the trial programme.
- British Airways, providing the HOMP data replay and analysis software and assisting the project with their long standing FDM experience.
- BAE Systems, providing the PCMCIA Card Quick Access Recorders (CQARs) for the trial aircraft.

The trial HOMP was developed and directed by an integrated project team, comprising representatives from the CAA, Shell Aircraft, ES-S, BHL and BA. The project team proved to be very effective in ensuring that the maximum information and benefits were obtained from the programme.

The trial was performed using five BHL Tiger (Super Puma) helicopters. Although helicopters moved between bases, the intention was to maintain two HOMP helicopters at Scatsta on the Shetland Islands and three at Aberdeen. This arrangement enabled an assessment of the logistics and management issues associated with the application of a HOMP to helicopters located at a remote base as well as at main base. The HOMP on-aircraft system is shown in Figure 3.1.

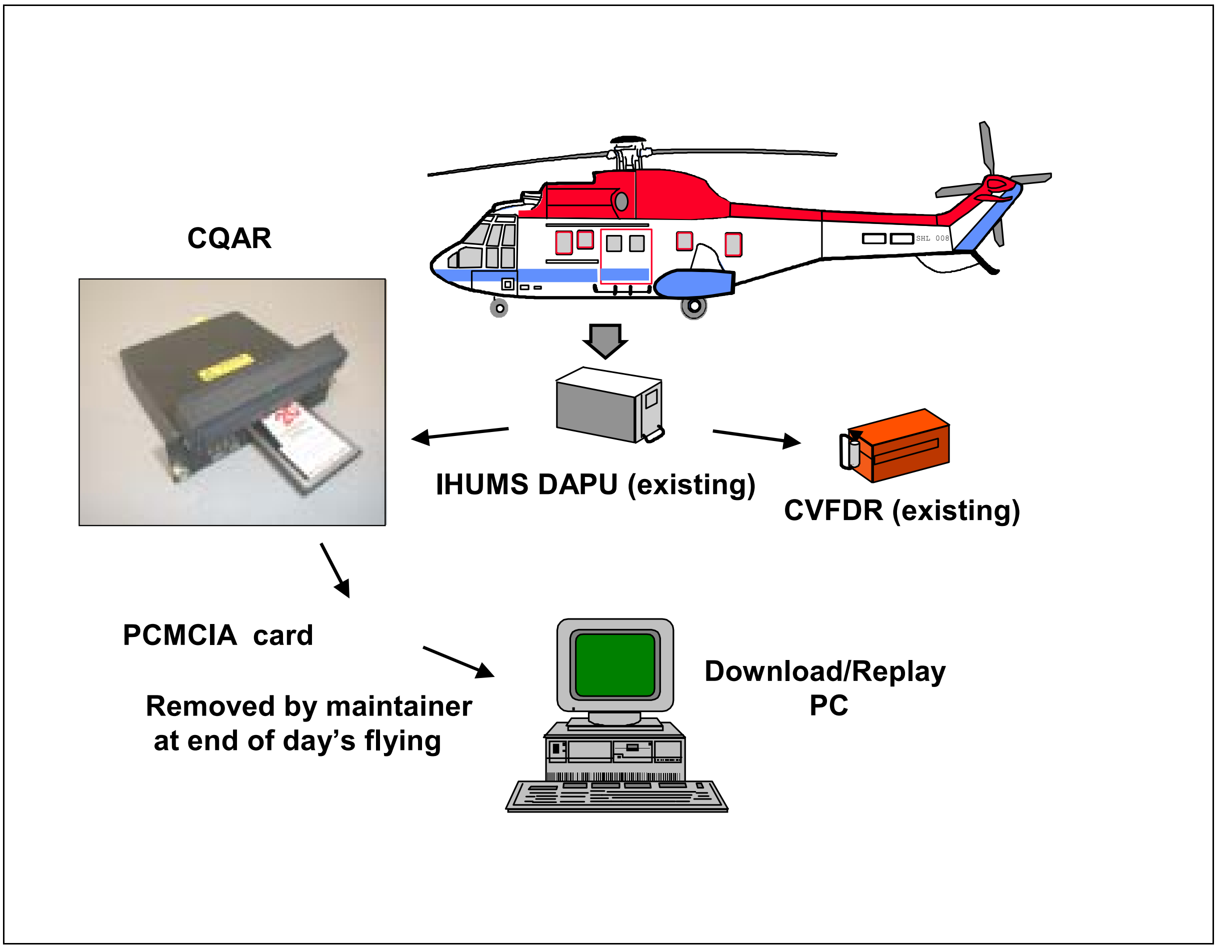


Figure 3.1 On-Aircraft System

The CQAR PCMCIA cards were changed once a day by maintenance personnel when the aircraft returned to the hangar; there was no pilot involvement with the system. The flight data was downloaded from the PCMCIA cards to a PC and the cards re-initialised for re-use. The HOMP ground-based system is shown in Figure 3.2.

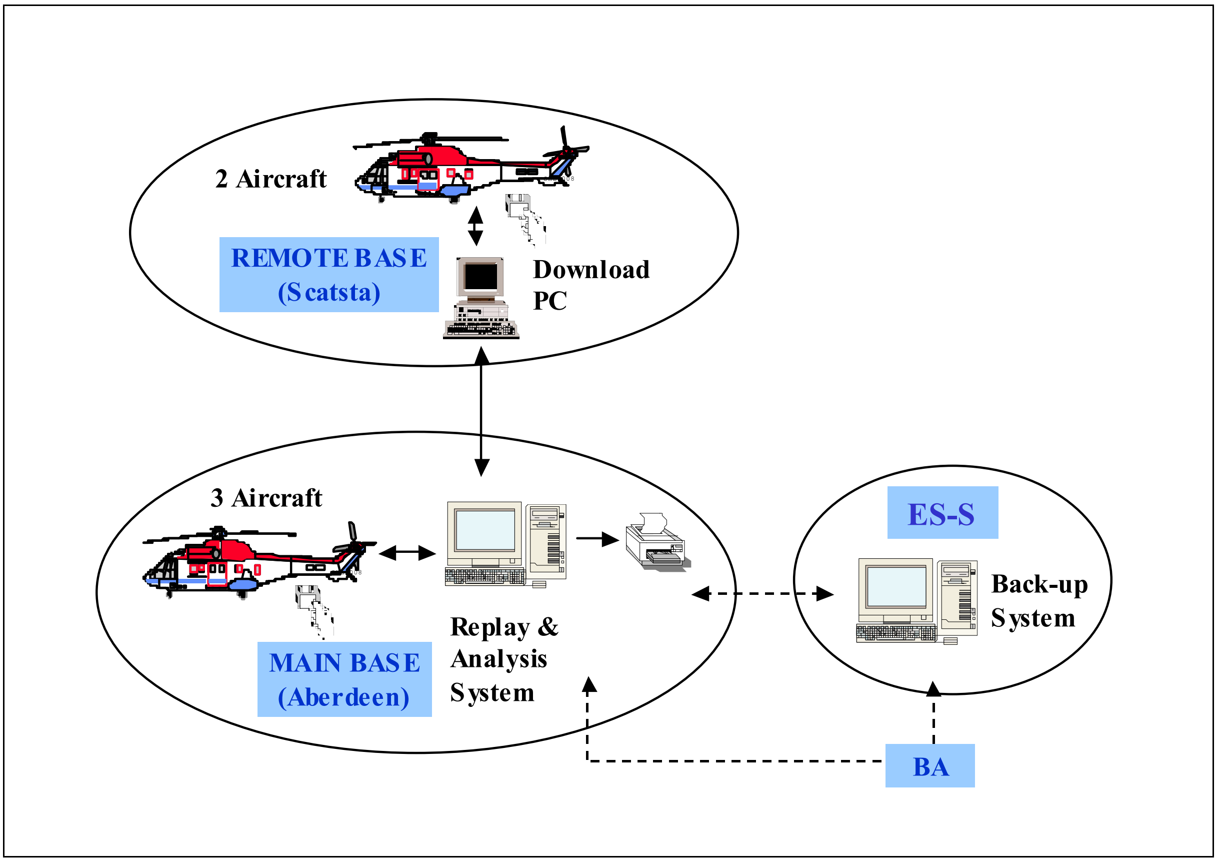


Figure 3.2 Ground-Based System

Every few days the flight data in the download PC at Scatsta was transferred to a zip disk and sent to Aberdeen for analysis. Approximately 1 Mb of data was recorded per hour, therefore in a typical day about 7 Mb of flight data and an additional 1 Mb of ground data were gathered per aircraft. With these file sizes, and no more than two HOMP aircraft located at Scatsta, it should have been feasible to transfer data electronically via a company network or the Internet. However the trial sought to evaluate the worst-case scenario in which such options might not be available, and the ability to send mail on regular fixed-wing charter flights prevented any significant data transfer delays.

All data analysis took place on the HOMP replay and analysis system at Aberdeen, and the trial monitoring programme was managed from there on a part-time basis by a senior training captain. The data from the Aberdeen aircraft was replayed on a daily basis, with the data from the Scatsta aircraft being replayed in a batch process whenever a zip disk was received. All the acquired flight data was retained to enable re-analysis at a future date.

A back-up HOMP system was installed at ES-S's facility in Southampton to enable ES-S to provide configuration, testing and ad-hoc analysis support to BHL. If necessary for troubleshooting purposes, BA could log into the HOMP systems at BHL and ES-S using “PC Anywhere”.

The model for BHL’s HOMP data analysis and programme management process is shown in Figure 3.3.

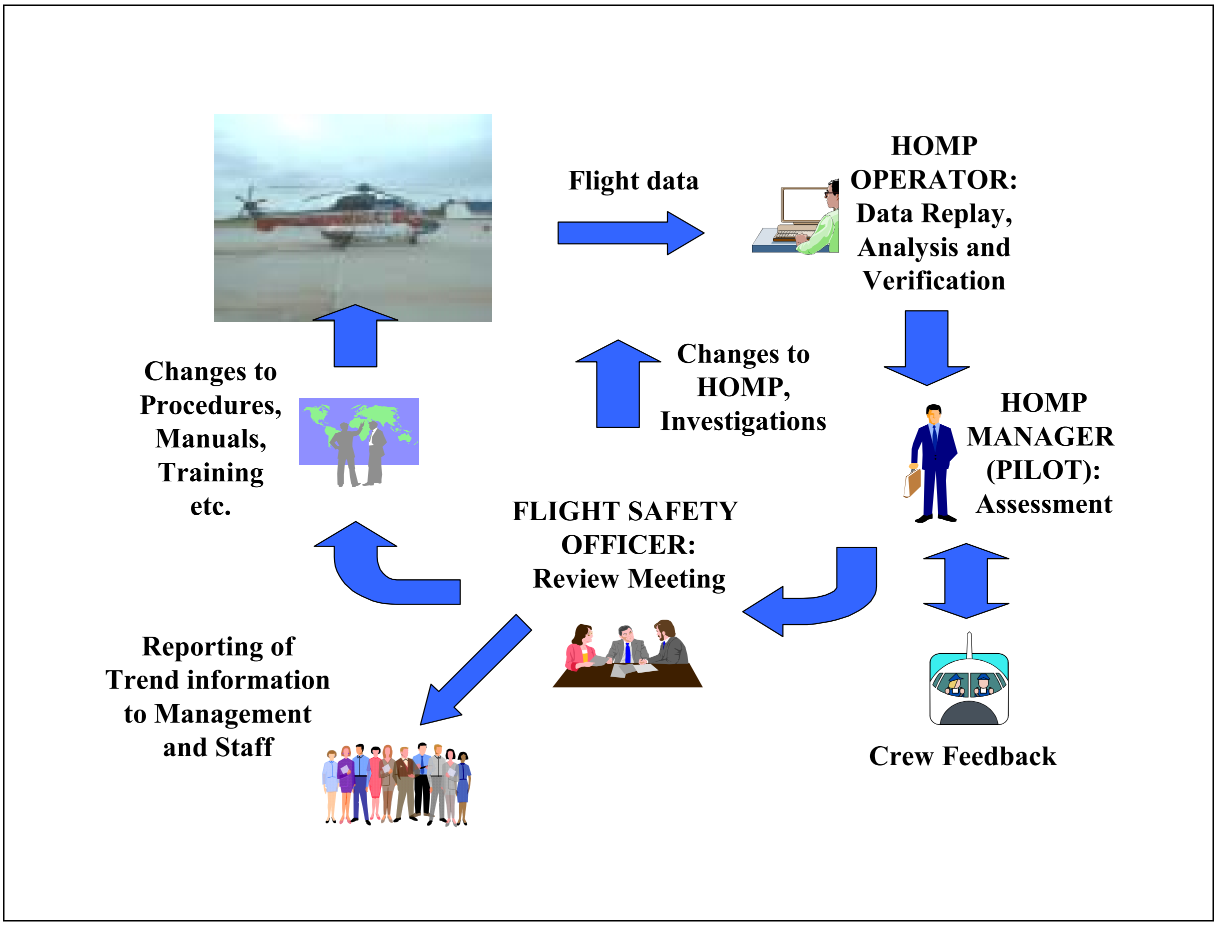


Figure 3.3 Model HOMP Process

The model process involves three key personnel:

- A HOMP Operator. This person is responsible for the routine replay and analysis of the flight data, and the initial verification of any events.
- A HOMP Manager. The HOMP Manager is a senior current pilot, ideally a training captain, who manages the overall programme, provides the 'expert pilot' input required for investigating events (calling on type-specific experience as required), and liases with aircrew if necessary. The HOMP Manager reports findings to the Flight Safety Officer. Alternatively, if a helicopter operator does not have a full time Flight Safety Officer, the two roles could be combined.
- A Flight Safety Officer (FSO). The FSO is an existing post and provides the link through which the HOMP integrates with the operator's existing safety management system. This person is responsible for deciding whether any actions need to be taken on the basis of the information provided by the HOMP Manager. Such actions could include recommending changes to company operating and/or training procedures and manuals, the initiation of special HOMP investigations, or recommending changes to the programme itself.

For the HOMP trial, BHL's senior training captain on the Super Puma performed the roles of both the HOMP Operator and Manager. He reviewed and assessed any events generated and, being a peer of the flight crew rather than a member of BHL's management, followed these up with aircrew if necessary. He also issued regular newsletters informing all BHL personnel of what was being learnt from the trial, and held periodic meetings with the Flight Safety Officer to review key event information.

An industry briefing was held for representatives of the North Sea helicopter operators and oil companies to provide information on what was being learnt from the trial and to obtain industry feedback. The UKOOA aircraft committee plus management, flight safety, and pilot association representatives from UK and European operators, together with representatives from the BHAB and BALPA, were invited to this briefing. A number of other briefings were also given, including one to the European Helicopter Operators Committee (EHOC). In addition, papers were presented at two Royal Aeronautical Society Conferences (References 11 and 12) and articles were published in three editions of the Helicopter World magazine (April-June 2001) to provide a wider dissemination of information on the HOMP trial.

Section 4 HOMP Trial Equipment and Data Analysis

4.1 On-aircraft equipment

The flight data generated by the BHL Tiger IHUMS Data Acquisition and Processing Unit (DAPU) was written to a PCMCIA card by the BAE Systems Card Quick Access Recorder (CQAR) Type 612/1/52937 shown in Figure 4.1.

Figure 4.1 CQAR

The CQAR utilises standard high capacity PCMCIA Type II ATA Flash PC cards. Cards of a capacity greater than 16 Mbytes must be used with the recorder, there is no upper limit on the capacity (20 and 48 Mbyte cards were used for the HOMP trial). A 'low' indicator is illuminated when the available free space on the card falls below 20% of the total card capacity. If the card is full, the CQAR will stop recording data. A card may be inserted into the unit either before the unit is powered up, or at any time following unit power up. The card may be removed from the unit at any time providing the 'busy' indicator is not illuminated (i.e. when data is being written to the card from an internal buffer). Cards are formatted using a DOS 16-bit FAT file system in order to ensure compatibility across the MS-DOS 6.21, Windows 95 and Windows NT 4.0 operating systems.

The CQAR input signal is an ARINC 573-7 bi-polar RZ (return to zero) signal from the auxiliary output from the IHUMS DAPU as defined in Attachment 10-5 of ARINC 573-7. The CQAR starts recording data when QAR data is received and the QAR interface (run control) is enabled. The QAR input is a continuous bit stream with the data in repeated frames and each frame comprising four sub-frames. The CQAR will accept 64, 128, 256 or 512 12-bit word subframes, the IHUMS DAPU outputs 256 word 2 second subframes (i.e. a data rate of 128 words per second). ARINC 12-bit words are stored as 16-bit words. Synchronisation of the data frames is achieved by embedded sync words in the data stream. The CQAR supports both the ARINC 573 and ARINC 717 standards.

The QAR input interface carries out checks on every frame received. The received frame is checked for the correct sync word in every subframe and for the correct frame size. Any failure of the above checks for 35 consecutive seconds will illuminate a 'QAR fail' indicator. Data recording is suspended during a QAR fail condition.

All data transferred to or from the CQAR resides in the card root directory. Files written to the card by the CQAR have 01-01-80 00:00:00 for the date and time of creation record in their directory entry. The QAR data files are named QARddd.DAT, where sequence numbers 'ddd' are in the range 0 to 511. During normal operation data will be appended to the current QAR file. A new QAR data file will be opened following; power up with the CQAR enabled, a CQAR enable, reception of bad data frames, power interruptions, or a CQAR hardware reset.

The physical characteristics of the CQAR are as follows:

Weight: 1.23 Lbs (0.56 Kilograms) (excluding card)
Unit Height: 1.50 inches (38.10 mm)
Unit Width: 5.75 inches (146.05 mm)
Unit Depth: 5.12 inches (130.05 mm) (excluding mating connector and earth stud)

For the HOMP trial the CQAR was mounted in the cockpit centre console, the unit being secured in place by two DZUS quarter turn camlock fasteners. The fasteners are arranged in standard DZUS rail format in accordance with Attachment 2 of ARINC 601. The CQAR operates from an aircraft +28V DC supply in accordance with RTCA DO-160D, Section 16.0 Category Z and Section 17.0 Category A. Connection to the unit is made via a single MIL-C-38999 Series II 37 pin circular bayonet coupling connector mounted on the rear of the unit.

The BHL Tiger aircraft parameters recorded by the CQAR and de-coded in the ground-based system are listed in Table 4.1, which also shows the parameter sample rates.

Table 4.1 BHL Tiger Aircraft Parameters

Parameter Name	Short name	Parameter Type	Sample Rate (Hz)
A/C Registration	A/C Reg	-	-
ALT mode engaged	APALT	Discrete	1
ASE 1 Pitch	ASE1PTCH	Discrete	1
ASE 1 Roll	ASE1ROLL	Discrete	1
ASE 1 Yaw	ASE1YAW	Discrete	1
ASE 2 Pitch	ASE2PTCH	Discrete	1
ASE 2 Roll	ASE2ROLL	Discrete	1
ASE 2 Yaw	ASE2YAW	Discrete	1
Captain's R/T	PTTP1	Discrete	1
Collective Pitch	COLLPTCH	Continuous	4
Co-Pilot’s R/T	PTTP2	Discrete	1
Date Day	DATEDD	-	-
Date Month	DATEMM	-	-
Date Year	DATEYY	-	-
DME No.1 Distance	DME1	Continuous	0.5
DME No.2 Distance	DME2	Continuous	0.5
Drift Angle	DRIFTA	Continuous	0.5
Event Marker	EVENT	Discrete	1
Framecount	FRMCNT	-	-
Fuel Contents LH	FUEL1	Continuous	0.5
Fuel Contents RH	FUEL2	Continuous	0.5
Gear Down - LH	GEARDLH	Discrete	1
Gear Down - Nose	GEARDNOS	Discrete	1
Gear Down - RH	GEARDRH	Discrete	1
Gear select up	GEARSELUP	Discrete	1
Glide Slope Deviation	GS	Continuous	1
Ground Speed	GSPD	Continuous	1
HDG Mode engaged	APHDG	Discrete	1
Heading (Magnetic)	HDGM	Continuous	1
Heater	HEATER	Discrete	1
IAS Mode engaged	APIAS	Discrete	1
Ice Detect Liq. Water Content	ICEDET	Continuous	2
Indicated Airspeed	IAS	Continuous	1
Intermediate Gearbox Oil Temp	IGBOILT	Continuous	0.5
Lateral Acceleration	LATA	Continuous	4
Lateral Cyclic Pitch	CYCPTCHLAT	Continuous	4
Latitude	LATLSP	Continuous	0.5

Table 4.1 BHL Tiger Aircraft Parameters

Localiser Deviation	LOC	Continuous	1
Longitude	LONGLSP	Continuous	0.5
Longitudinal Acceleration	LNGA	Continuous	4
Longitudinal Cyclic Pitch	CYCPTCHLONG	Continuous	4
Main G/box Oil Temp	MGBOILT	Continuous	0.5
Main Gearbox Oil Pressure	MGBOILP	Continuous	1
Main Rotor Speed (Nr)	MRSPEED	Continuous	2
MLS Azimuth	MLSAZ	Continuous	1
MLS Elevation	MLSEL	Continuous	1
Nf 1 (No 1 Free Turbine Speed)	EFTS1	Continuous	2
Nf 2 (No 2 Free Turbine Speed)	EFTS2	Continuous	2
Ng 1 (No 1 Gas Generator rpm)	EGGS1	Continuous	4
Ng 2 (No 2 Gas Generator rpm)	EGGS2	Continuous	4
Normal Acceleration	NMLA	Continuous	8
Outside Air Temperature	OAT	Continuous	1
Pitch Attitude	PITCH	Continuous	4
Pressure Altitude	PALTC	Continuous	1
Radio Altitude	RALT	Continuous	2
RNAV Mode engaged	APRNAV	Discrete	1
Roll Attitude	ROLL	Continuous	4
Rotor Brake	RBRAKE	Discrete	1
Sling Load	SLING	Continuous	2
Sync Bit	SYNCBIT	-	-
T4 1 (No 1 Exhaust Gas Temp)	EGT1	Continuous	2
T4 2 (No 2 Exhaust Gas Temp)	EGT2	Continuous	2
Tail Rotor Gearbox Oil Temp	TRGBOILT	Continuous	0.5
Tail Rotor Pedal	TRPEDAL	Continuous	4
TIME GMT (hrs)	GMTHH	-	-
TIME GMT (min)	GMTMM	-	-
Torque Engine 1	TORQ1	Continuous	2
Torque Engine 2	TORQ2	Continuous	2
Vertical Speed (from DIGITAS)	ALTRATE	Continuous	2
Weight On Wheels	WGHTONWH	Discrete	1
Wind Angle	WINDANGLE	Continuous	0.5
Wind Speed	WINDSPEED	Continuous	0.5
Yaw Rate	YAWRATE	Continuous	4

4.2 Ground-based equipment

A data download PC was provided for downloading PCMCIA card data from helicopters operating remotely at Scatsta. The primary method of data transfer to the HOMP system at Aberdeen was by zip disc, however a modem was installed to provide an option to e-mail data across the Internet.

A networked PC was provided to run the HOMP software at Aberdeen. This PC analysed the data downloaded from the PCMCIA cards from the aircraft at Aberdeen together with the data transferred by zip disc from the PC at Scatsta. When cards were inserted into the PCMCIA card reader the raw flight data files were automatically copied to a known directory on the computer's hard disk to await processing by the HOMP software. The specification of the PC was as follows:

Processor	Intel 550MHz Pentium III
Memory	128MB
Hard Drive	15.3GB
Floppy Drive	1.44MB 3.5" Diskette Drive
CD-RW Drive	
PCMCIA card reader	
Monitor	21" colour Monitor
Zip Drive	Iomega Internal ATAPI Zip Drive
Modem	56K Modem with gateway.net Internet Access
Network Card	3COM PCI 10/100 Twisted Pair Ethernet
Tape Backup Unit	TR5 10/20GB IDE Internal
Operating System	MS Windows NT
Application software	MS Office 2000 Professional + MS Access 2000
Colour printer	HP DeskJet 1220C

A third PC was located at ES-S, also running the HOMP software to provide support for the main system at Aberdeen. Data could be transferred between BHL and ES-S using the following media; PCMCIA cards, CDs, tapes and email.

4.3 HOMP software

The HOMP software comprised the four flight data modules in the British Airways Safety Information System (BASIS). Since its inception in 1990, BASIS has become the leading aviation safety management tool and the de facto standard air safety reporting tool. The system is used by approximately 150 organisations including major airlines, regulatory authorities and aircraft manufacturers. North Sea helicopter operators were already using the BASIS Air Safety Reporting module.

The BASIS flight data modules run on standard PCs and can be network based. One advantage of the BASIS analysis software is that it has been developed with the assistance and co-operation of both flight crew and management, both of whom use the system on a day to day basis. Security safeguards have been built into the various BASIS flight data modules to ensure that the stored information is appropriately de-identified to all except a few nominated personnel. The four BASIS flight data modules are described below.

4.3.1 Flight Data Traces (FDT)

FDT performs the flight data replay, event and measurement analysis, and displays flight data traces. The module's intuitive and user configurable design is intended to allow non-specialists to operate and maintain the system. The module performs the following functions:

- Reads in the raw flight data from the aircraft's onboard flight data recorder.
- Automatically detects events defined by the operator.
- Automatically extracts a set of flight data measurements.
- Stores traces and events for future analysis.
- Displays selected flight data and detected events as a trace or listing on screen.
- Produces outputs to other BASIS flight data modules.
- Analyses flight data associated with Air Safety Reports.

When processing data, FDT automatically replays all the downloaded flight data, detects events and extracts flight data measurements. When used for data investigation it provides numerical listings and graphical traces to enable the user to investigate and classify events. A typical trace display is shown in Figure 4.2. FDT provides facilities for the user to configure the flight parameter decode, the calculation of derived parameters from the basic parameter set, the event definitions and event limits or constants, the flight data measurements, and flight data trace displays.

The module performs an automatic five-step process when reading the raw flight data files:

Step 1: Parameter Decode

The FDT software monitors the directory where the copied files have been placed and will automatically capture and decode any new files found in it. The decode procedure converts the raw flight data into engineering units using a set of standard parameter decode equations (specific to the QAR frame layout). For the HOMP trial, FDT decoded approximately 70 parameters (variables and discretes). Not all parameters stored on the QAR need to be configured or decoded in FDT. Indeed, the smaller the number of parameters processed the quicker the decode phase will be. FDT automatically determines departure and arrival locations based on the latitude and longitude at take-off and landing.

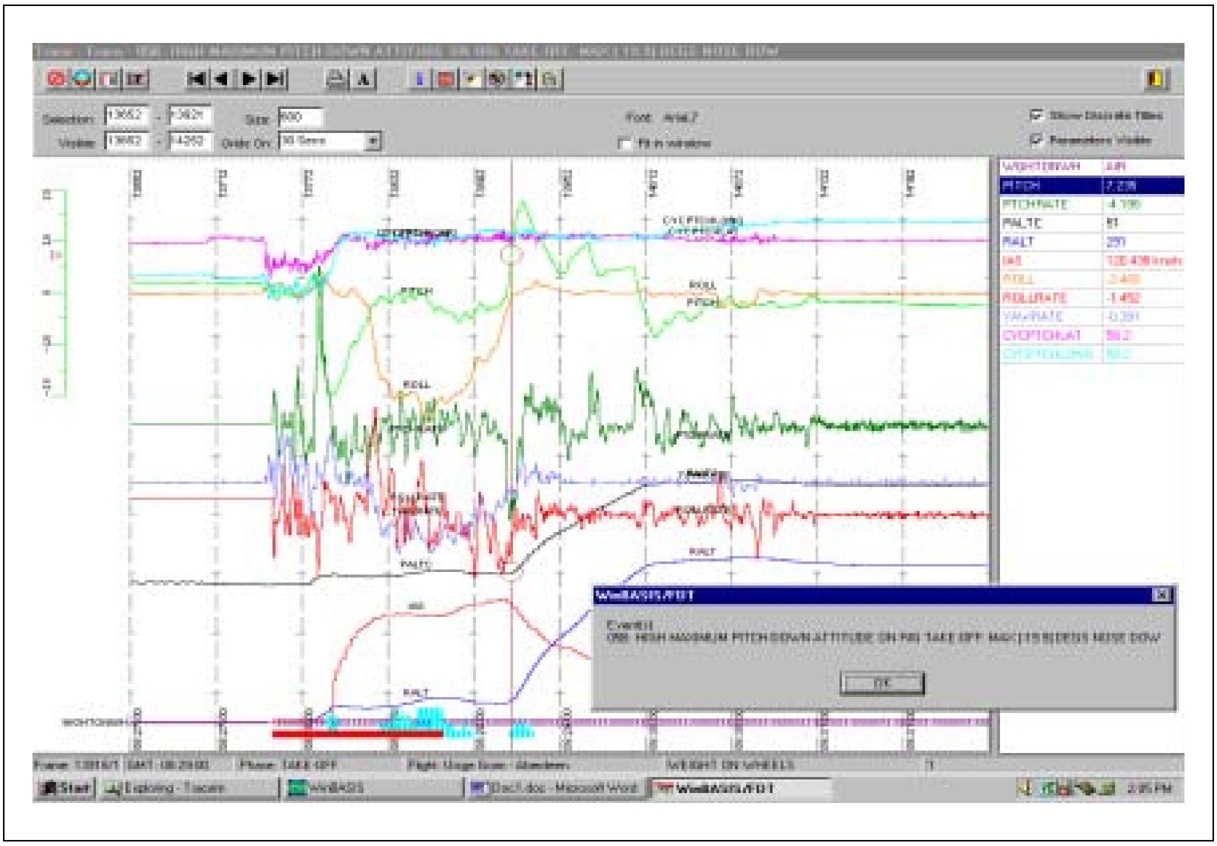


Figure 4.2 Sample Trace From Super Puma FDT

Step 2: Flight Phases

FDT then determines the flight phases based on the data recorded; there normally are several flights on each PMCIA card. The user can configure these flight phases using simple logic statements. The flight phases used in the HOMP trial were:

1 On-ground (prior to take-off)

2 Take-off

3 Cruise

4 Landing

5 On-ground (after landing)

Step 3: Derived parameters

There are a number of parameters that are not available directly from the QAR but which are needed for detecting events. Such parameters are referred to as derived parameters. FDT uses the now decoded QAR parameters and the flight phases to calculate a number of derived parameters (e.g. Density Altitude for Vne/Vno). FDT calculates a day/night parameter which can be used to determine whether an event occurred in daylight or darkness.

Step 4: Event Detection

FDT now searches all of the decoded data for pre-defined events. These events normally involve applying limits to one or more parameters (or derived parameters) when in a particular flight phase or phases. The event definitions are totally configurable by the operator and can be extremely complex logical equations if required. A total of 85 events were configured in the HOMP trial (for comparison, BA monitors 63 events on the B777 fleet).

Step 5: Flight Data Measurements

The final step in this automatic FDT process is the capture of a set of flight data measurements which are maximum or "worst case" values of selected parameters (including derived parameters) under specified conditions, or parameter values at specific points of a flight or when specific events occur. Approximately 140 measurements were extracted in the HOMP trial (BA uses 70 on the B777 fleet).

Once all the five steps are complete FDT accepts the decoded file as a new record in its database. The record appears as a line of information on the front screen (browse list). One of the columns shows the number of events detected and the user can double click on the line to look at these events in detail (Figure 4.3). Alternatively the user can review events in a browser which enables all events to be accessed from a central area, removing the need to access these from individual flight data files.

With experience, the user can normally quickly determine if the event is genuine by looking at the data trace, the numerical listing and/or the Flight Data Simulation (FDS) for the event. Nuisance or false events can be marked as such within FDT, these can then be deleted or excluded from further analysis. If the nuisance or false events are regular and predictable then the event definition in FDT can be altered to eliminate these. Once the user has determined which events are genuine, the details of these events can now be exported to the FDE (Flight Data Events) module. FDT creates three files for each event:

- A cut-down raw data file just for that event
- A file with the necessary event details for FDE
- A file to simulate the event using FDS

FDT will also export a measurement data file to the BASIS FDM (Flight Data Measurements) module, irrespective of whether any events have been detected for a given flight.

In addition to the event and measurement analysis, FDT has an automatic serviceability output function which enables automatic extractions of flight data to be scheduled at specified intervals for checking of the FDR parameters.

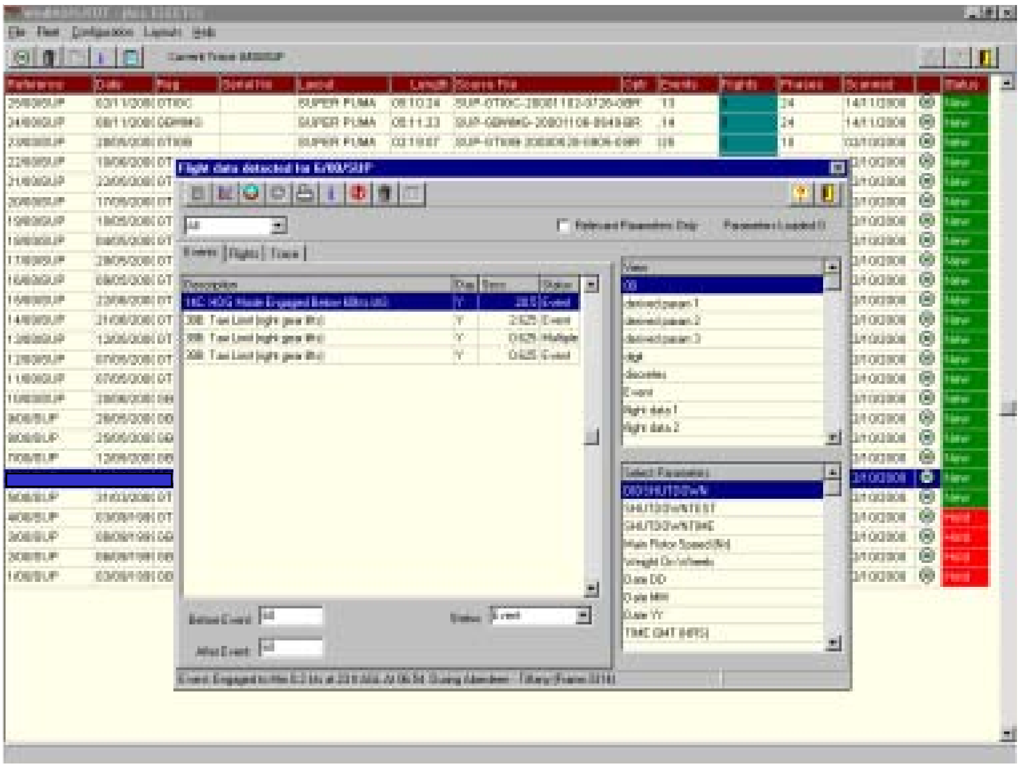


Figure 4.3 Events Detected List in FDT

4.3.2 Flight Data Simulation (FDS)

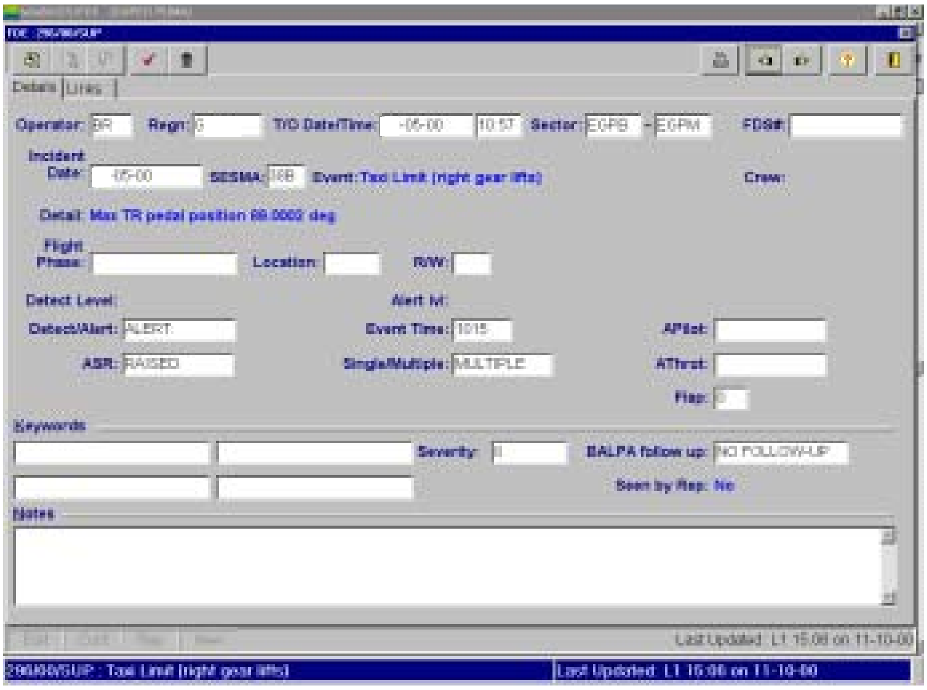
FDS recreates the flight just as the pilot saw it, allowing data to be viewed in the form of a basic flight instrument simulation. The flight controls and autopilot modes are also displayed and the aircraft flight path is shown. A new version of this module, simulating a Super Puma cockpit, was produced for the HOMP trial. FDS is a valuable tool for use in the event investigation process, and is also a powerful debriefing aid when it is necessary to involve the aircrew to understand the circumstances and causes of a particular event. The self-contained nature, and very small size, of the viewing program allows it and the relevant portion of flight data to be e-mailed or sent on a floppy disk to aircrew for their review on any PC. This can be particularly useful for debriefing crews at remote operating bases. The Super Puma FDS display is shown in Figure 4.4.

Figure 4.4 Super Puma FDS Display

4.3.3 Flight Data Events (FDE)

FDE enables further analysis of the events generated by FDT. FDE receives verified event records exported from FDT and stores these in its database. Events imported into FDE are given unique reference numbers and stored by fleet type. With the addition of FDV (the Flight Data Viewer), the user can view the raw data associated with each event as a trace, listing or flight simulation directly from the event record within FDE.

The user can add keywords and notes to event forms and track any follow up actions (Figure 4.5). The system can be (and is at BA) linked to the BASIS Air Safety Reporting (ASR) module. If the pilot has raised an ASR for the event held in FDE, then this obviously relevant information can be viewed alongside the event details.



Operator: BR
Regn: G
T/O Date/Time: -05-00 10:57
Sector: EGPB - EGPM
FDS#:
Incident Date: -05-00
SESMA: 16B
Event: Taxi Limit (right gear lifts)
Crew:
Detail: Max TR pedal position 69.0002 deg
Flight Phase:
Location:
R/W:
Detect Level:
Alert lvl:
Detect/Alert: ALERT
Event Time: 10:15
APilot:
ASR: RAISED
Single/Multiple: MULTIPLE
AThrst:
Flap:
Keywords
Severity:
BALPA follow up: NO FOLLOW-UP
Seen by Rep: No
Notes
Last Updated: L1 15:08 on 11-10-00
296/00/SUP : Taxi Limit (right gear lifts)
Last Updated: L1 15:08 on 11-10-00

Figure 4.5 FDE Event Form

FDE enables the user to manually allocate a numerical value (severity index) to each event to indicate the relative severity of that event. FDE also allows the user to enter severity equations so that it can automatically calculate a severity index for each imported event. This enables the analysis of event trends based on cumulative severity measures, rather than simply on frequency of occurrence. The severity index enables event trends to be related to degrees of operational risk, and is therefore a valuable management tool. BA have developed severity equations for their SESMA programme, however these are specific to the fixed wing events, and therefore could not be applied to the helicopter events implemented in the HOMP trial. As an alternative to the allocation of severity values within FDE, it is possible to manually allocate values in FDT and import these into FDE.

The module can be used to analyse events by aircraft type, registration, event type, location, date, keyword etc. Events can easily be filtered using a range of criteria and the filtered subset of the data can be displayed in a variety of ways. Trend charts can be produced using various parameters; e.g. the top events in a given fleet (either by frequency or severity), worst locations for certain landing events etc. Once created, these charts can be stored in a trend library for rapid recall. Operational data such as the number of sectors flown by aircraft type and movements at locations can be imported into FDE allowing trend charts to show rated data such as the number of events per 1,000 sectors. An appropriate date range can be specified, and graphs can be produced showing the change in event numbers over a current period compared to a previous period. The trend charts can be used to identify adverse trends or patterns, to measure the effectiveness of past resolutions to problems, and to monitor the effect of changes to SOPs. A typical trend chart is shown in Figure 4.6.

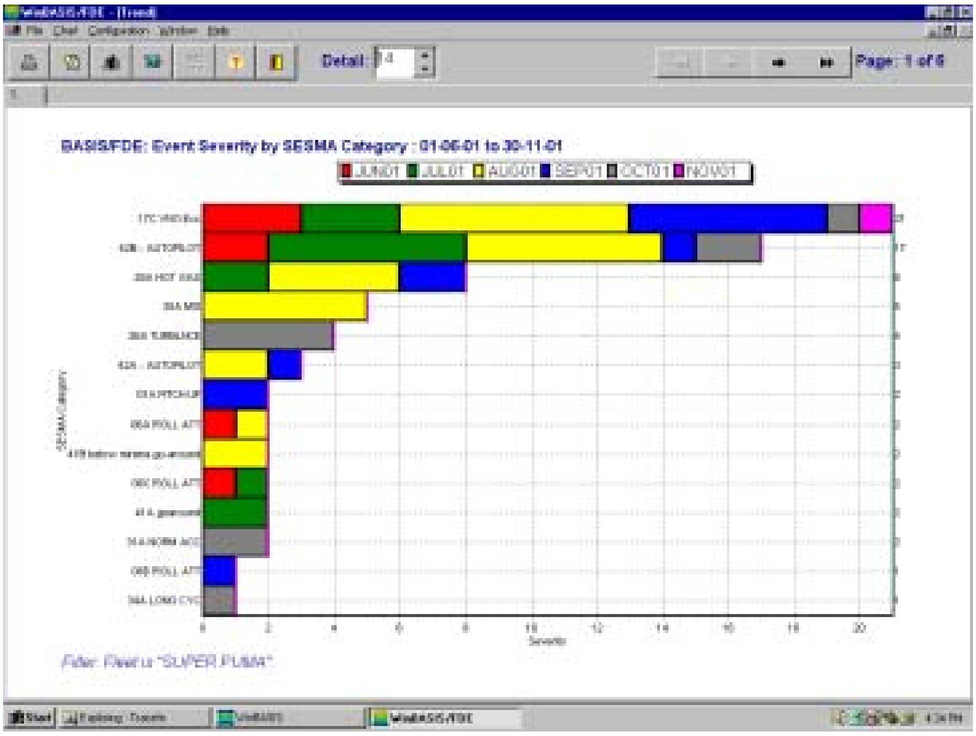


Figure 4.6 Typical FDE Trend Chart

4.3.4 Flight Data Measurements (BASIS FDM)

BASIS FDM is a tool for analysing the flight data measurements extracted by FDT, enabling the analysis of flight parameter values on each and every flight and showing how parameters are distributed over many flights. Exported measurement data from FDT is imported into FDM and again stored by fleet type.

FDM facilitates a better understanding of operational variables by showing their ‘normal’ distributions and enabling comparisons of distributions across different locations, fleets etc. Two distributions can be compared on the same chart; e.g. the same flight data parameter on another aircraft type, registration, location, date range or against a standard normal distribution. The mean and standard deviation are automatically calculated for each distribution and can also be plotted to illustrate the spread of the measurements.

FDM information can be used in conjunction with the analysis provided by FDE. This can help to determine whether certain events are isolated occurrences or whether there have been many more “near misses” just below the event limit. Information from FDM is also useful for the setting of meaningful event limits for FDT. An example BASIS FDM display is shown in Figure 4.7:

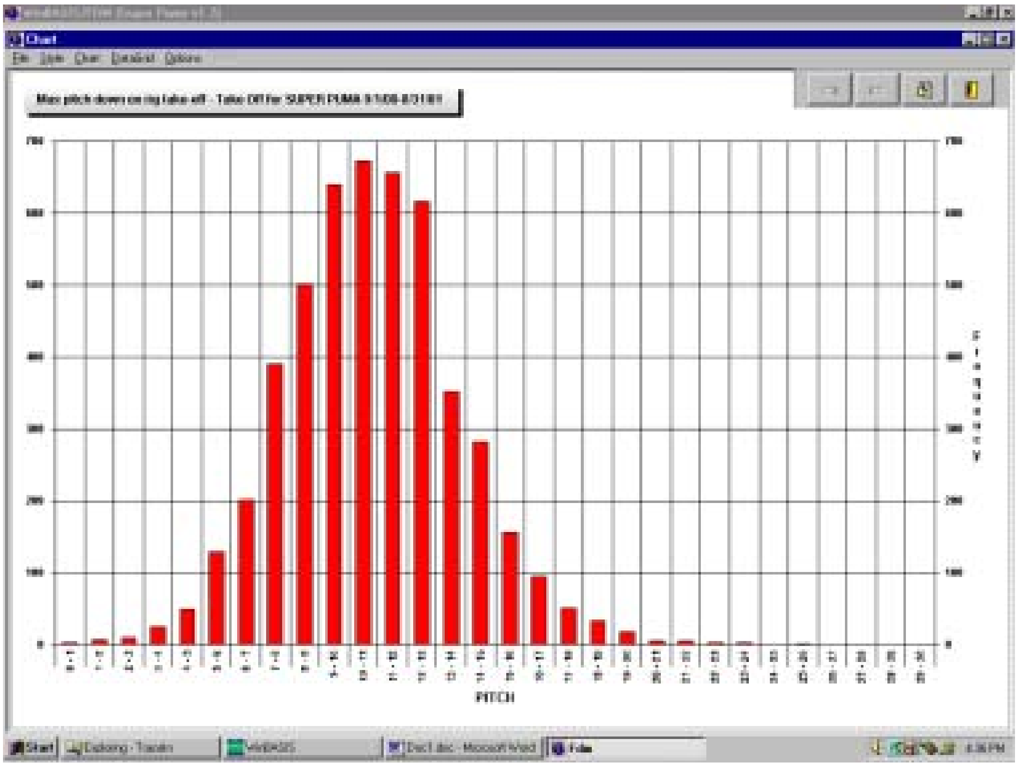


Figure 4.7 Typical BASIS FDM Display

4.4 HOMP data analysis

As explained previously, the HOMP software performs two types of analysis:

- Event analysis, which provides information on the extremes of the operation.
- Measurement analysis, which provides information on the whole operation.

An initial set of flight data events was specified by the HOMP trial project team at the start of the trial. The flight data measurements were specified part way through the trial after the events had been implemented. Towards the end of the trial an additional set of offshore take-off and landing profile measurements were implemented.

The events and measurements were subject to continuous development and by the end of the trial comprehensive sets of events and measurements had been produced. These are presented in Tables 4.2 to 4.6. Tables 4.2 and 4.4 show the HOMP events and measurements grouped by type and the flight phase in which they are calculated. Tables 4.3 and 4.5 present listings of all the events and measurements. Table 4.6 lists the additional offshore take-off and landing profile measurements which were implemented at the end of the trial.

Table 4.2 HOMP Events Grouped by Type and Flight Phase

	On Ground before Take-off	Take-off/Climb	Cruise	Descent/Approach/ Landing	On Ground after Landing
FLT PROFILE		• High/Low pitch attitude at rotation point (for rig t/o) • High/Low pitch rate at rotation point (for rig t/o) • Early turn at night • Gear up early • Downwind flight	• Low height in cruise	• Go around • Low height on go around • Gear down late • Downwind flight	
SPEED	• High taxi speed	• High rate of descent • High rate of descent at low airspeed • Low airspeed	• VNO/VNE exceedance • High rate of descent • High rate of descent at low airspeed • Low airspeed	• VNO/VNE exceedance • High rate of descent • High rate of descent at low airspeed • High groundspeed on approach	• High taxi speed
ATTITUDE	• High pitch attitude (up/ down) • High roll attitude	• High pitch attitude (up/ down) • High pitch rate • High roll attitude • High roll rate	• High pitch attitude (up/ down) • High pitch rate • High roll attitude • High roll rate	• High pitch attitude (up/ down) • High pitch rate • High roll attitude • High roll rate	• High pitch attitude (up/ down) • High roll attitude

Table 4.2 HOMP Events Grouped by Type and Flight Phase

	On Ground before Take-off	Take-off/Climb	Cruise	Descent/Approach/ Landing	On Ground after Landing
CONTROLS	• Rollover limits • Autopilot engagement • Excessive cyclic longitudinal pitch • High cyclic lateral rate • High cyclic longitudinal rate	• Excessive collective pitch • Excessive cyclic longitudinal pitch • Excessive cyclic lateral pitch • Inappropriate autopilot modes	• Excessive collective pitch • Excessive cyclic longitudinal pitch • Excessive cyclic lateral pitch • Inappropriate autopilot modes	• Excessive collective pitch • Excessive cyclic longitudinal pitch • Excessive cyclic lateral pitch • Inappropriate autopilot modes	• Rollover limits • Autopilot engagement • Excessive cyclic longitudinal pitch • High cyclic lateral rate • High cyclic longitudinal rate
ACCELS	• High Deck Motion Severity Index • High lateral acceleration • High longitudinal acceleration	• High lateral acceleration • High longitudinal acceleration • High normal acceleration	• High lateral acceleration • High longitudinal acceleration • High normal acceleration	• High lateral acceleration • High longitudinal acceleration • High normal acceleration • High normal acceleration on landing	• High Deck Motion Severity Index • High lateral acceleration • High longitudinal acceleration
POWERTRAIN	• High main rotor speed	• Heater on during take-off • High/Low main rotor speed power on • High/Low main rotor speed power off • High torque • Single engine flight	• High/Low main rotor speed power on • High/Low main rotor speed power off • High torque • Torque split • Single engine flight	• Heater on during landing • High/Low main rotor speed power on • High/Low main rotor speed power off • High torque • Single engine flight	• High main rotor speed • Rotor brake application
OTHER		• Flight through hot gas	• Low fuel contents	• Pilot workload/ turbulence • Flight through hot gas • Low fuel contents	

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
01A	High Pitch-Up Attitude Below 20 ft AGL	Air	Pitch Attitude, Radio Altitude	To detect the risk of a tail rotor strike.
01B	High Pitch-Up Attitude Above 20 ft and Below 500 ft AGL	Air	Pitch Attitude, Radio Altitude	To detect excessive flare angle i.e. rushed final approach, likely to alarm passengers or cause crew to lose visual reference.
01C	High Pitch-Up Attitude Above 500 ft AGL	Air	Pitch Attitude, Radio Altitude	To detect excessive pitch up attitude in flight.
01D	High Pitch-Up Attitude Below 90 knots IAS	Air	Pitch Attitude, Indicated Airspeed	To detect excessive pitch up attitude at lower speeds.
01E	High Pitch-Up Attitude Above 90 knots IAS	Air	Pitch Attitude, Indicated Airspeed	To detect excessive pitch up attitude at higher speeds.
02A	High Pitch-Down Attitude Below 20 ft AGL	Air	Pitch Attitude, Radio Altitude	To detect excessive nose down pitch attitude during take-off transition which might result in striking the ground if an engine failed.
02B	High Pitch-Down Attitude Above 20 ft and Below 500 ft AGL	Air	Pitch Attitude, Radio Altitude	To detect excessive nose down pitch attitude during take-off transition and at other lower level flight conditions.
02C	High Pitch-Down Attitude Above 500 ft AGL	Air	Pitch Attitude, Radio Altitude	To detect excessive pitch down attitude in flight.
02D	High Pitch-Down Attitude Below 90 knots IAS	Air	Pitch Attitude, Indicated Airspeed	To detect excessive pitch down attitude at lower speeds.
02E	High Pitch-Down Attitude Above 90 knots IAS	Air	Pitch Attitude, Indicated Airspeed	To detect excessive pitch down attitude at higher speeds.

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
03A	High Pitch Rate Below 500 ft AGL	Air	Pitch Rate, Radio Altitude	To detect excessive rate of change of pitch attitude at lower level flight conditions.
03B	High Pitch Rate Above 500 ft AGL	Air	Pitch Rate, Radio Altitude	To detect excessive rate of change of pitch attitude in flight.
04A	Low Maximum Pitch Rate on Rig Take-Off	Rig Take-Off	Pitch Rate	To detect a low helicopter rotation rate during rotation on a take-off from a helideck which could result in a deck strike if an engine failed.
04B	High Maximum Pitch Rate on Rig Take-Off	Rig Take-Off	Pitch Rate	To detect a high helicopter rotation rate during rotation on a take-off from a helideck, which might cause crew disorientation and passenger alarm.
05A	Low Maximum Pitch-Down Attitude on Rig Take-Off	Rig Take-Off	Pitch Attitude	To detect a low nose down pitch attitude during rotation on a take-off from a helideck, which could result in a deck strike if an engine failed.
05B	High Maximum Pitch-Down Attitude on Rig Take-Off	Rig Take-Off	Pitch Attitude	To detect a high nose down pitch attitude during rotation on a take-off from a helideck, which might cause crew disorientation and passenger alarm.
06A	Roll Attitude Above 30 deg Below 300 ft AGL	Air	Roll Attitude, Radio Altitude	To detect exceedance of the Flight Manual roll attitude limit for weights above 18,410 lb at lower level flight conditions.
06B	Roll Attitude Above 40 deg Below 300 ft AGL	Air	Roll Attitude, Radio Altitude	To detect exceedance of the Flight Manual roll attitude limit for weights above 17,200 lb at lower level flight conditions.
06C	Roll Attitude Above 30 deg Above 300 ft AGL	Air	Roll Attitude, Radio Altitude	To detect exceedance of the Flight Manual roll attitude limit for weights above 18,410 lb.
06D	Roll Attitude Above 40 deg Above 300 ft AGL	Air	Roll Attitude, Radio Altitude	To detect exceedance of the Flight Manual roll attitude limit for weights above 17,200 lb.
07A	High Roll Rate Below 500 ft AGL	Air	Roll Rate, Radio Altitude	To detect excessive roll rate at lower level flight conditions.

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
07B	High Roll Rate Above 500 ft AGL	Air	Roll Rate, Radio Altitude	To detect excessive roll rate in flight.
08A	High Rate of Descent Below 500 ft AGL	Air	Rate of Descent, Radio Altitude	To detect an excessive rate of descent at low height.
08B	High Rate of Descent Above 500 ft AGL	Air	Rate of Descent, Radio Altitude	To detect an excessive rate of descent.
08C	High Rate of Descent Below 30 knots LAS	Air	Rate of Descent, Indicated Airspeed	To detect an excessive rate of descent at low airspeed (where there is danger of entering the vortex ring state).
09A	Low Airspeed Above 500 ft AGL	Take-Off, Cruise	Indicated Airspeed	To detect flight at an unusually low airspeed.
10A	Normal Acceleration Above 500 ft AGL	Air	Normal Acceleration, Radio Altitude	To detect a high normal acceleration in flight due to turbulence or a manoeuvre.
10B	Normal Acceleration Below 500 ft AGL	Air	Normal Acceleration, Radio Altitude	To detect a high normal acceleration at lower level flight conditions due to turbulence or a manoeuvre.
10C	Lateral Acceleration Above 500 ft AGL	Air	Lateral Acceleration, Radio Altitude	To detect a high lateral acceleration in flight due to turbulence or a manoeuvre.
10D	Lateral Acceleration Below 500 ft AGL	Air	Lateral Acceleration, Radio Altitude	To detect a high lateral acceleration at lower level flight conditions due to turbulence or a manoeuvre.
10E	Longitudinal Acceleration Above 500 ft AGL	Air	Longitudinal Acceleration, Radio Altitude	To detect a high longitudinal acceleration in flight due to turbulence or a manoeuvre.
10F	Longitudinal Acceleration Below 500 ft AGL	Air	Longitudinal Acceleration, Radio Altitude	To detect a high longitudinal acceleration at lower level flight conditions due to turbulence or a manoeuvre.
11A	Excessive Lateral Cyclic Control	Air	Lateral Cyclic Pitch	To detect movement of the lateral cyclic control to extreme left or right positions.

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
11B/C	Excessive Longitudinal Cyclic Control	Air	Longitudinal Cyclic Pitch	To detect movement of the longitudinal cyclic control to extreme forward or aft positions.
12A	Excessive Collective Pitch Control in Level Flight	Air	Collective Pitch, Rate of Descent	To detect approaches to, or exceedances of, Flight Manual collective pitch limits for cruising flight.
12B	Excessive Collective Pitch Control	Air	Collective Pitch	To detect exceedances of the absolute maximum Flight Manual collective pitch limit.
13A	Pilot Event Marker Pressed	Air		To detect when the FDR pilot event marker has been pressed.
14A	IAS Mode Engaged Below 60 knots IAS	Air	Autopilot IAS Mode, Indicated Airspeed	To detect inappropriate engagement of autopilot airspeed hold at low airspeeds.
14B	ALT Mode Engaged Below 60 knots IAS	Air	Autopilot ALT Mode, Indicated Airspeed	To detect inappropriate engagement of autopilot altitude hold at low airspeeds.
14C	HDG Mode Engaged Below 60 knots IAS	Air	Autopilot HDG Mode, Indicated Airspeed	To detect inappropriate engagement of autopilot heading hold at low airspeeds.
15A	Gear Selected Up Below 100 ft AGL on Take-off	Take-Off	Gear Select, Radio Altitude	To detect early retraction of the landing gear during take-off.
15B	Gear Not Selected Down Below 300 ft AGL on Landing	Landing	Gear Select, Radio Altitude	To detect late lowering of the landing gear during landing.
16A	Excessive Time in Avoid Area			Not yet implemented (awaiting low airspeed algorithm).
17A/C	VNO Exceedance	Air	VNO, Weight	To detect exceedance of the Flight Manual VNO limit (this is weight dependent).
17B/D	VNE Exceedance	Air	VNE, Weight	To detect exceedance of the Flight Manual VNE limit (this is weight dependent).

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
18A	No. 1 (LH) Fuel Contents Low	Air	LH Fuel Contents	To detect if the total remaining fuel contents fall below the Operations Manual limit.
18B	No. 2 (RH) Fuel Contents Low	Air	RH Fuel Contents	To detect if the total remaining fuel contents fall below the Operations Manual limit.
19A	Heater On During Take-Off	Take-Off	Heater	To detect non-conformance with the Flight Manual requirement that the cabin heater should be off during take-off.
19B	Heater On During Landing	Landing	Heater	To detect non-conformance with the Flight Manual requirement that the cabin heater should be off during landing.
20A	Early Turn on Offshore Take-Off at Night	Rig Take-Off	Heading, Ground Speed	To detect an early turn after an offshore take-off at night.
21A	High Ground Speed Within 20 seconds of Rig Landing	Rig Landing	Ground Speed	To detect a high ground speed on the final approach to a helideck landing.
21B	High Ground Speed Within 10 seconds of Airport Landing	Airport Landing	Ground Speed	To detect a high ground speed on the final approach to an airport landing.
22A	High Airspeed Below 100 ft AGL	Air	Indicated Airspeed, Radio Altitude	To detect high speed flight at low level.
22B	High Airspeed Below 100 ft AGL and Gear Up	Air	Indicated Airspeed, Radio Altitude, Gear Select	To detect high speed flight at low level with the landing gear retracted.
23A	Downwind Flight Within 60 seconds of Take-Off	Take-Off	Indicated Airspeed, Ground Speed	To detect downwind flight shortly after take-off.
23B	Downwind Flight Within 60 seconds of Landing	Landing	Indicated Airspeed, Ground Speed	To detect downwind flight shortly before landing.
24A	Low Rotor Speed – Power On	Air	Rotor Speed, Total Torque	To detect excessively low rotor speed during power-on flight.

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
24B	High Rotor Speed – Power On	Air	Rotor Speed, Total Torque	To detect excessively high rotor speed during power-on flight.
24C	Low Rotor Speed - Power Off	Air	Rotor Speed, Total Torque	To detect exceedance of the Flight Manual minimum rotor speed limit for power-off flight.
24D	High Rotor Speed – Power Off	Air	Rotor Speed, Total Torque	To detect exceedance of the Flight Manual maximum rotor speed limit for power-off flight.
25A	Maximum Continuous Torque (2 Engines)	Air	Total Torque	To detect more than 5 minutes use of the Flight Manual take-off rating torque limit
25B	Maximum Take-Off Torque (2 Engines)	Air	Total Torque	To detect exceedance of the Flight Manual absolute maximum torque limit.
26A	Pilot Workload/Turbulence	Landing	Changes in Collective Pitch	To detect turbulence encountered during the final approach to a helideck landing.
27A	Pilot Workload	Landing	Collective, Lateral & Longitudinal Cyclic	Not yet implemented (awaiting outcome of CAA research project).
28A	Flight Though Hot Gas	Take-Off, Landing	Outside Air Temperature	To detect if the aircraft flies through the turbine efflux or flare plume during a helideck take-off or landing.
29A	High Pitch-Up Attitude on Ground	Ground	Pitch Attitude	To detect high aircraft pitch angles when on a vessel’s helideck, or on sloping ground.
29B	High Pitch-Down Attitude on Ground	Ground	Pitch Attitude	To detect high aircraft pitch angles when on a vessel’s helideck, or on sloping ground.
30A	High Roll Attitude on Ground	Ground	Roll Attitude	To detect high aircraft roll angles during taxiing, when on a vessel’s helideck, or on sloping ground.
31A	High Normal Acceleration at Landing	Landing, Ground	Normal Acceleration	To detect a heavy landing.

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
32A	High Rotor Speed on Ground	Ground	Rotor Speed	To detect possible governor problems on the ground.
33A	Rotor Brake Applied at Greater Than 122 Rotor RPM	Ground	Rotor Brake, Rotor Speed	To detect application of the rotor brake above the Flight Manual limit for rotor speed.
34A	Excessive Long Cyclic Control with Insufficient Collective Pitch on Ground	Ground	Collective Pitch, Longitudinal Cyclic Pitch	To detect incorrect taxi technique likely to cause rotor head damage.
34B	Excessive Rate of Movement of Longitudinal Cyclic on Ground	Ground	Longitudinal Cyclic Pitch Rate, Rotor Speed	To detect an excessive rate of movement of the longitudinal cyclic control when on the ground with rotors running.
34C	Excessive Rate of Movement of Lateral Cyclic on Ground	Ground	Lateral Cyclic Pitch Rate, Rotor Speed	To detect an excessive rate of movement of the lateral cyclic control when on the ground with rotors running.
35A/B	Excessive Movement of Deck	Helideck	Motion Severity Index	To detect excessive movement of a vessel's helideck when the helicopter is on the deck.
36A	High Lateral Acceleration (rapid cornering)	Ground	Lateral Acceleration	To detect excessive cornering accelerations/speeds when taxiing.
36B	High Longitudinal Acceleration (rapid braking)	Ground	Longitudinal Acceleration	To detect excessive deceleration due to braking when taxiing.
37A	High Ground Speed	Ground	Ground Speed	To detect excessive taxiing speeds.
38A	Taxi Limit (left gear lifts)	Ground	Lateral Cyclic Pitch, Tail Rotor Pedal	To detect the risk of an aircraft roll over due to incorrect tail rotor pedal and lateral cyclic control positions when taxiing.
38B	Taxi Limit (right gear lifts)	Ground	Lateral Cyclic Pitch, Tail Rotor Pedal	To detect the risk of an aircraft roll over due to incorrect tail rotor pedal and lateral cyclic control positions when taxiing.

Table 4.3 Listing of HOMP Events

Event Number	Title	Applicable Condition	Trigger Parameters	Rationale
39A	Single Engined flight	Air	No 1 Eng Torque, No 2 Eng Torque	To detect single engined flight.
40A	Torque Split in the Cruise	Cruise	No 1 Eng Torque, No 2 Eng Torque	To detect a possible engine problem, subsequently found to have been caused by module 2 stator vane rotation.
41A	Go Around	Cruise, Landing	Gear Select	To detect a go-around.
41B	Below Minimum Height on Go Around	Cruise, Landing	Gear Select, Radio Altitude	To detect a descent below the minimum height limit during a go around.
41C	Below Minimum Height on Go Around at Night	Cruise, Landing	Gear Select, Radio Altitude	To detect a descent below the minimum height limit during a go around at night.
42A	Autopilot Engaged On Ground Before Take-Off	Ground	Autopilot Status	To detect premature engagement of the autopilot prior to take-off which could result in unexpected control movements.
42B	Autopilot Engaged On Ground After Landing	Ground	Autopilot Status	To detect failure to disengage the autopilot after landing which could result in unexpected control movements.

Table 4.4 HOMP Flight Data Measurements Grouped by Type and Flight Phase

	On Ground before Take-off	Take-off/Climb	Cruise	Descent/Approach/ Landing	On Ground after Landing
FLT PROFILE		• Press alt at t/o • Max pitch attitude at rotation (for rig t/o) • Max pitch rate at rotation (for rig t/o) • Radio alt at rotation (for rig t/o) • Radio alt at gear up	• Max Press alt • Max airspeed at low height	• Press alt at landing • Radio alt at gear down	
SPEED	• Max taxi speed	• Max rate of descent • Max rate of descent at low airspeed • Min airspeed	• Max rate of descent • Max rate of descent at low airspeed • Max/Min airspeed	• Max rate of descent • Max rate of descent at low airspeed • Max/Min airspeed • Groundspeed on approach	• Max taxi speed
ATTITUDE	• Max/Min pitch attitude • Max roll attitude	• Max/Min pitch attitude • Max pitch rate • Max roll attitude • Max roll rate • Max yaw rate	• Max/Min pitch attitude • Max pitch rate • Max roll attitude • Max roll rate • Max yaw rate	• Max/Min pitch attitude • Max pitch rate • Max roll attitude • Max roll rate • Max yaw rate	• Max/Min pitch attitude • Max roll attitude
CONTROLS	• Max cyclic longitudinal pitch • Max cyclic lateral rate • Max cyclic longitudinal rate	• Max collective pitch • Max cyclic longitudinal pitch • Max cyclic lateral pitch • Min airspeeds for autopilot modes	• Max collective pitch • Max cyclic longitudinal pitch • Max cyclic lateral pitch • Min airspeeds for autopilot modes	• Max collective pitch • Max cyclic longitudinal pitch • Max cyclic lateral pitch • Min airspeeds for autopilot modes	• Max cyclic longitudinal pitch • Max cyclic lateral rate • Max cyclic longitudinal rate

Table 4.4 HOMP Flight Data Measurements Grouped by Type and Flight Phase

	On Ground before Take-off	Take-off/Climb	Cruise	Descent/Approach/ Landing	On Ground after Landing
ACCELS	• Max Deck Motion Severity Index • Max lateral acceleration • Max longitudinal acceleration	• Max lateral acceleration • Max longitudinal acceleration • Max normal acceleration	• Max lateral acceleration • Max longitudinal acceleration • Max normal acceleration	• Max lateral acceleration • Max longitudinal acceleration • Max normal acceleration • Peak normal acceleration on landing	• Max Deck Motion Severity Index • Max lateral acceleration • Max longitudinal acceleration
POWERTRAIN	• Max main rotor speed • Max EGT at engine start	• Max/Min main rotor speed power on • Max/Min main rotor speed power off • Max torque • Max EGT • Max engine gas generator speed • Max MGB/IGB/TGB oil temp • Max/Min MGB oil press	• Max/Min main rotor speed power on • Max/Min main rotor speed power off • Max torque • Max EGT • Max engine gas generator speed • Max MGB/IGB/TGB oil temp • Max/Min MGB oil press	• Max/Min main rotor speed power on • Max/Min main rotor speed power off • Max torque • Max EGT • Max engine gas generator speed • Max MGB/IGB/TGB oil temp • Max/Min MGB oil press	• Max main rotor speed • Main rotor speed at rotor brake application • Max EGT at engine start
OTHER		• OAT at take-off • Take-off weight • Fuel contents at t/o • Wind speed/direction • Max increase in OAT		• OAT at landing • Landing weight • Fuel contents at landing • Max pilot workload/ turbulence • Wind speed/direction • Max increase in OAT	

Table 4.5 Listing of HOMP Flight Data Measurements

Measurement	Applicable Condition	Values
Pitch below 20ft AGL	Air	Max +ve, Min –ve
Pitch between 20ft and 500ft AGL	Air	Max +ve, Min –ve
Pitch above 500ft AGL	Air	Max +ve, Min –ve
Pitch below 90kts IAS	Air	Max +ve, Min –ve
Pitch above 90kts IAS	Air	Max +ve, Min –ve
Pitch rate below 500ft AGL	Air	Max absolute
Pitch rate above 500ft AGL	Air	Max absolute
Roll below 300ft AGL	Air	Max absolute
Roll above 300ft AGL	Air	Max absolute
Roll rate below 500ft AGL	Air	Max absolute
Roll rate above 500ft AGL	Air	Max absolute
Yaw rate	Air	Max +ve, Min –ve
Rate of Descent below 500ft AGL	Air (Individual phases)	Max
Rate of Descent above 500ft AGL	Air (Individual phases)	Max
Rate of Descent below 30kts IAS	Air (Individual phases)	Max
IAS above 500ft AGL	Air	Min
Lateral acceleration above 500ft AGL	Air	Max absolute
Lateral acceleration below 500ft AGL	Air	Max absolute
Longitudinal acceleration above 500ft AGL	Air	Max absolute

Table 4.5 Listing of HOMP Flight Data Measurements

Measurement	Applicable Condition	Values
Longitudinal acceleration below 500ft AGL	Air	Max absolute
Normal acceleration above 500ft AGL	Air	Max absolute
Normal acceleration below 500ft AGL	Air	Max absolute
Lateral cyclic control	Air	Max , Min
Longitudinal cyclic control	Air	Max, Min
Collective pitch control	Air (Individual phases)	Max
IAS at which IAS mode engaged IAS at which ALT mode engaged IAS at which HDG mode engaged	Air	Min Min Min
IAS	Air	Max
IAS below 100ft AGL	Air	Max
Main rotor speed above 10% total torque	Air	Max, Min
Main rotor speed below 10% total torque	Air	Max, Min
Total torque	Air (Individual phases)	Max
Increase in OAT	Air	Max
Ng engine 1	Air (Individual phases)	Max
Ng engine 2	Air (Individual phases)	Max
Engine gas temperature engine 1	Air (Individual phases)	Max
Engine gas temperature engine 2	Air (Individual phases)	Max
Ice detector	Air	Max
IGB oil temperature	Air	Max

Table 4.5 Listing of HOMP Flight Data Measurements

Measurement	**Applicable Condition**	**Values**
MGB oil pressure	Air	Max, Min
MGB oil temperature	Air	Max
TGB oil temperature	Air	Max
Pressure altitude	Air	Max
Pilot workload/turbulence (collective only)	Air	Max
Pitch	Ground	Max, Min
Roll	Ground	Max absolute
Main rotor speed	Ground	Max
Longitudinal cyclic control	Ground	Max
Longitudinal cyclic control rate	Ground	Max absolute
Lateral cyclic control rate	Ground	Max absolute
Motion Severity Index (excluding airports)	Ground	Max
Lateral acceleration	Ground	Max absolute
Longitudinal acceleration	Ground	Max absolute
Ground speed	Ground	Max
NMLA datum value	When calculated	Value
Fuel contents tank 1	At take-off	Value
Fuel contents tank 2	At take-off	Value
Fuel remaining tank 1	At landing	Value
Fuel remaining tank 2	At landing	Value

Table 4.5 Listing of HOMP Flight Data Measurements

Measurement	**Applicable Condition**	**Values**
Aircraft weight	At take-off	Value
Aircraft weight	At landing	Value
Rad alt at gear selected up	At gear up	Value
Rad alt at gear selected down	At gear down	Value
Normal acceleration at landing	At landing	Max
MR speed at application of rotor brake	MR brake applied	Value
Engine gas temperature, engine 1	At engine start	Max
Engine gas temperature, engine 2	At engine start	Max
Pitch rate, rig take-off	At rotation point	Max
Pitch, rig take-off	At rotation point	Max
Rad alt, rig take-off	At max pitch rate	Value
Ground speed, rig landing	Point before landing	Value
Ground speed, airport landing	Point before landing	Value
Pressure altitude	At take-off	Value
Pressure altitude	At landing	Value
OAT	At take-off	Value
OAT	At landing	Value
Average wind speed	Point after TO & before LDG	Value
Average wind direction	Point after TO & before LDG	Value

Table 4.6 Additional HOMP Flight Profile Measurements

Measurement Point	Comments	Measurements
RIG TAKE-OFF PROFILE		
1 Lift-off	Take-off reference point	Time, Pressure Altitude, Latitude, Longitude
2 Rotation – Maximum Pitch Rate	Usually coincides with start of rotation	Time from Take-Off, Radio Altitude, Pressure Altitude (AAL), Pitch, Roll, Heading, Airspeed, Groundspeed, Latitude (N/S distance from take-off), Longitude (W/E distance from take-off)
3 Rotation – Maximum Pitch Down Angle	Usually coincides with end of rotation	
4 35 knots Airspeed	Lift-off point if airspeed greater than 35 kts at lift-off	
5 Vy (Climb Speed)	Obtained from Flight Manual	
6 Gear Selected Up	End of take-off phase if gear not retracted by then	
7 200 Feet AAL	Definition of climb out path	
8 500 Feet AAL	Definition of climb out path	
9 1,000 Feet AAL	Definition of climb out path	
RIG LANDING PROFILE		
1 Touch-down	Landing reference point	Time, Pressure Altitude, Latitude, Longitude
2 35 knots Airspeed	Start of low airspeed phase	Time to Landing, Radio Altitude, Pressure Altitude (AAL), Pitch, Roll, Heading, Airspeed, Groundspeed, Latitude (N/S distance from landing), Longitude (W/E distance from landing)
3 Gear Selected Down	Start of landing phase if gear already down by then	
4 1,000 Feet AAL	Definition of approach path	
5 500 Feet AAL	Definition of approach path	
6 200 Feet AAL	Definition of approach path	
7 Maximum Pilot Workload	Workload based on collective only	

Section 5 HOMP Trial Operational Experience

5.1 Project programme

The project started in January 1999. The initial phase, involving development and production of the CQAR and also development and configuration of the HOMP software, continued until August 1999. The CQARs were delivered at the end of August and the gathering of flight data from the trials aircraft commenced in September 1999. The operational phase of the trial was therefore considered to have started on 1 September 1999, with the first year of trial operations continuing until 31 August 2000. The first release of the HOMP software was installed at BHL in Aberdeen in early October 1999. This was followed by a period of system commissioning, during which the performance of the HOMP software was assessed prior to the trial going 'live'. All the flight data collected during the commissioning period was analysed and reviewed, with one of the key tasks being to substantially reduce the large number of "nuisance events" initially generated. The commissioning period was completed in December 1999, at which time the trial was considered to be ‘live’.

The initial period of the operational phase of the trial concentrated on the application of the event detection process to the downloaded flight data. Work continued on the specification of the flight data measurements during this period, and the release of a new version of the HOMP software in early July 2000 enabled all the specified measurements to be implemented. The configuration of the flight data measurements was completed in September 2000, enabling the collection of measurement data to commence.

A contract extension was granted to continue the operational phase of the trial for a second year from 1 September 2000 to 31 August 2001. During this period there was an increased emphasis on the generation of event trend information and on safety management procedures for taking corrective actions based on HOMP events, then monitoring the effect of these actions. Further HOMP software upgrades between March and May enabled the manual allocation of severity levels to events and a prototype severity scale was developed. The completion date of the trial was extended to the end of October 2001 to enable the gathering of 6 months of trend data for events with severity levels allocated. Development and refinement of the HOMP events and measurements continued throughout the second year of trial operations. A set of offshore take-off and landing profile measurements were implemented towards the end of the trial. Archived HOMP data for the period September 2000 to August 2001 was then reprocessed to generate a database of measurements covering a one year period.

5.2 On-aircraft system

5.2.1 Aircraft installation

It was recognised that there were variations in the types of main gyros and radio altimeters fitted to BHL's Tiger helicopters. To enable the correct FDR parameter decodes to be configured for the trials aircraft, the specific aircraft that would be included in the trial were identified, together with their equipment fits.

Once the necessary CQAR documentation had been received from BAE Systems, the aircraft modification was completed and the modification kits built. The modification was straightforward, with the CQAR being provided with a power supply and an ARINC 573 input from the IHUMS DAPU. The kits were subsequently installed in the aircraft, with the CQAR being mounted in the cockpit centre console.

The DAPU was powered from the battery bus and therefore acquired data whenever there was power on the aircraft. It was recognised that the CQAR would be recording data at the same time and would therefore record data during any overnight maintenance work requiring power to be on the aircraft. The majority of the PCMCIA cards used for the HOMP trial had a 20MB capacity, which equated to approximately 20 hours of data recording (some 48MB cards were also used). It was therefore possible that, depending on how often a PCMCIA card was downloaded, occasionally a card could become full and some flight data be lost. However, this did not occur provided the cards were changed on a daily basis. All the data files generated when there was power on the aircraft for maintenance work were deleted during the data scanning process on the HOMP PC.

For future installations, the CQAR could be made to record data only when the rotors are turning by utilising a ‘QAR enable’ input, for example connecting this to the right hand hydraulic pressure switch (which is used for a similar purpose in the rotor brake aural warning circuit). However, this would prevent any data recording during engine starts. Although no starting problems were encountered during the trial, one of the benefits of a HOMP is its ability to monitor “one-off” events, therefore it is considered useful to be able to monitor engine starts. If the CQARs are used for combined HUMS and HOMP data recording the PCMCIA cards will be inserted and removed by pilots before and after flights, which will eliminate the problem of filling the cards with data acquired during maintenance in the hangar. Therefore there are currently no plans to utilise the ‘QAR enable’ input.

Early trial experience showed that FDT had to cope with a large amount of ‘bad data’ as a result of spurious outputs from the aircraft DAPU when some sensors or systems were not powered up (e.g. pitch and roll gyros when AC power was off). The DAPU outputs were investigated to determine whether there were any parameters which could be used to determine when sensors or systems were off-line. It was confirmed that there was no discrete to indicate whether the 26V instrument supply transformers had been selected on. One proposal was to use a transistor switch to toggle a normally inactive discrete such as 'Battery Hot' to indicate the presence of 26V AC on the instrumentation bus. However the requirement for any such aircraft modification was to be avoided if at all possible as the philosophy of the trial was to have a minimum impact on the aircraft. The preferred solution was to trap bad data produced by off-line sensors within FDT and, with the subsequent enhancements made to FDT, false events caused by sensors or systems which were off-line became an infrequent occurrence.

5.2.2 CQARs

The CQARs were delivered at the end of August 1999 and operated correctly from first installation in the aircraft. It is estimated that, during the two years of operations, a total of 13,500 operating hours were accumulated on the five units. Both the CQARs and PCMCIA cards proved to be very reliable with very few problems being encountered.

One CQAR was damaged due to incorrect insertion of the PCMCIA card, which resulted in this becoming jammed in the unit. The CQAR was returned to BAE Systems for repair, where it was found that the card jam and CQAR damage had been caused by the card being inserted upside down and then forced in. This was the only known incidence of an incorrectly orientated card insertion causing a problem. By the end of the two year period of operations only one PCMCIA card had failed as a result of damage. Three others showed some evidence of crush damage, but were still functional.

Due to the tolerance in the CQAR card guides, some difficulty was occasionally encountered when attempting to insert a PCMCIA card. BAE Systems have subsequently modified the card guides to eliminate the problem.

One minor problem initially encountered was that, occasionally, a PCMCIA card was found to have a corrupted file allocation table. It was noted that the corruption only occurred if the cards were full. When the cards were changed on a daily basis no further problems occurred. BAE Systems identified a software bug and produced a modification to correct this. One CQAR was returned to BAE Systems for a firmware update in May 2000 to incorporate the QAR bug fix. Although not part of the HOMP trial, the opportunity was taken to install IHUMS Maintenance Data Recorder (MDR) software at the same time. The MDR functionality was to enable the future storage of HUMS data files on the CQAR and should have had no effect on the HOMP. However, when the CQAR was returned to BHL and installed in an aircraft, an 'MDR fail light' illuminated. The unit was returned to BAE Systems, where it was confirmed that the illumination of the MDR fail light had been caused by a hardware fault.

The HOMP trial was stopped in September 2000 for what was intended to be a two week period to enable the remaining CQARs to undergo the firmware update, however it was a month before the CQARs were returned. All units functioned correctly upon re-installation.

Occasionally a CQAR file was found to have been closed part way though a flight and a new file opened. This created problems during the data replay as information on the affected flight was split over two files. The cause of the ‘split files’ was believed to be the CQAR opening a new file following a loss of synchronisation after the receipt of bad data frames from the DAPU. The rate of occurrence of split files was quantified as 1.7 per week (there were 15 occurrences of file breaks in the 9 week period from 3/2/00 to 5/4/00). Whilst losing the small amount of data associated with the split files was not significant, they did create some difficulties with the data analysis. To overcome the problem, BHL produced a small program to re-join split files before these were scanned by FDT. Although no explanation for it was given, the occurrence of split files virtually ceased following the CQAR firmware update in September 2000.

During a period of monitoring data recovery rates it was found that, occasionally (i.e. typically once every two weeks), the CQAR failed to record a data file. When a case of a missing file was investigated it was found that no IHUMS data had been recorded on that flight, thus there had been nothing for the CQAR to record. Unfortunately, occasional missing IHUMS downloads were not logged or investigated as they only occurred infrequently and had many potential causes (e.g. a DAPU, MDR, or card problem, or a card not being inserted). Therefore no single cause of the occasional missing CQAR files could be identified.

5.2.3 Data collection

A total of approximately 11,500 hours of data was gathered between early September 1999 and the end of August 2001. This included the time the aircraft were powered-up by flight crew before or after a flight.

A very good data collection rate of between 90 and 95% was achieved, excluding the periods when one CQAR was undergoing repair, and when all the CQARs were having a firmware update. These exclusions were justified as, in order to collect the maximum amount of data, a deliberate decision was made to utilise all the CQARs purchased for the trial, and operate without any spare units. When a loss of data occurred, this was generally because of a failure to change the PCMCIA cards before they became full (especially over the weekend), or because of the limited fleet fit. For example, if one of the aircraft participating in the HOMP trial was sent to Scatsta or returned to Aberdeen (which could happen at short notice), it was necessary for personnel to remember that it was a HOMP aircraft, transfer the PCMCIA cards between the locations, and start changing the cards daily at the new location. When aircraft went into the hangar for heavy maintenance, which could last several weeks, it was again necessary to remember to re-start changing the cards once the aircraft was back on line. Typically this did not happen without the intervention of the HOMP Manager.

Any or all of the following options would further improve the data collection rate:

- Use PCMCIA cards with a capacity of more than 20MB (some 48MB cards were introduced in the second year of the trial).
- Adjust the installation modification to utilise the QAR enable pin to record data only when rotors are turning (but this would prevent recording during engine starts).
- Fit the entire fleet with CQARs so that downloading the cards becomes a routine action.
- Combine HUMS maintenance data recording with HOMP data recording using the CQAR only. This would ensure that data is downloaded by aircrew after each flight, which is a requirement for compliance with current CAA legislation for HUMS. This is the long term solution which is likely to be implemented by BHL.

During the two year trial, only a single instance was identified of a pilot removing a PCMCIA card during rotors running after realising that he had just done something likely to trigger a HOMP event. Fortunately, the relevant data had already been captured and the event was subsequently detected by the HOMP system.

A number of defects in the acquired flight parameters were noted during the trial. Detecting these defective parameters was a real benefit of the HOMP as rectification work could then take place, significantly increasing the probability that all FDR parameters would be available if needed for their primary function of incident/accident investigation. In the absence of a HOMP, FDR parameters are only required to be checked once per year. In addition, a number of these parameters had intermittent faults which may not have been detected during the annual check.

Towards the end of the trial the PCMCIA card reader ceased to function in the data collection PC at Scatsta. This coincided with the installation of additional printer driver software on the machine. With no dedicated computer support at this remote base, rectifying the problem was not straightforward and approximately one week of data had been lost by the time this was resolved.

5.3 HOMP software

The BASIS FDS, FDE and FDM software modules had previously been used by BA for their SESMA programme. FDT was a new module and the HOMP trial was the first application of it. It was also the first application in which FDT was integrated with the FDS, FDE and FDM modules. The HOMP software was subject to continuous development and improvement throughout the trial. A brief development history is given below, the reasons for some of the developments are explained in the following sections.

5.3.1 Software development history

To support the initial development and testing of the HOMP software prior to the installation of the CQARs, flight data was downloaded from the flight data recorders installed in two BHL Tiger helicopters. Some problems were encountered with inconsistencies in the aircraft documentation specifying the FDR parameter decode equations, which hampered the implementation of the flight data decoding in FDT.

A preliminary release of the HOMP software was installed at ES-S in August 1999 and evaluated using the downloaded FDR data. The first full release (version 1.0) of the software was installed at ES-S in September, where it was tested using CD's of CQAR data sent from BHL. Version 1.0 of the HOMP software was then installed at BHL in Aberdeen at the beginning of October 1999. Software development continued, with improvements being implemented in response to operational experience gained during the trial. There were eight new software versions during the two years of trial operations, some incorporated minor improvements whilst others introduced significant new functionality:

- Version 1.1, issued in November 1999
- Version 1.2, issued in November 1999
- Version 1.3, issued in January 2000
- Version 1.4, issued in July 2000
- Version 2.1, issued in March 2001
- Version 2.2, issued in May 2001
- Version 2.3, issued in May 2001
- Version 2.6, issued in September 2001

Some of the functionality improvements are listed below, further explanation of the reasons for them is given in Sections 5.4 and 5.5.

5.3.1.1 Improvements to system administration and data handling

Automatic re-naming of the CQAR files downloaded from the PCMCIA cards into the following format: fleet-registration-date-time-number.dat. The file names (QARx.dat where x is an incremental number) and dates (01-01-1980) generated by the CQAR provided no information on the origin or time of creation of the data files.

Improved file handling, automatically transferring the many "on-ground - no engines running" files to a "delete" directory, the "on-ground - engine running" files to a "no event" directory and all "flight" files to the "flight data" directory. This modification was required to eliminate the large number of CQAR files created when aircraft power was on during maintenance in the hangar.

5.3.1.2 Improvements to data analysis facilities

Provision of a facility to import flight information from BHL’s Operations database, and reference imported flight information (see Section 5.4.3.2).

Incorporation of a status box and notes field for each file in the main browse list (see Section 5.4.3.5).

Incorporation of a day/night derived parameter and event tag (see Section 5.4.3.4).

A modification to chain together multiple events of the same type which occur within a configurable time period of each other. This modification prevented the generation of large numbers of events when a parameter value was close to the event limit, causing frequent exceedances.

The inclusion of more complex and generic functions for derived parameter calculation, with the ability to calculate one derived parameter from another. This enhanced the capabilities and flexibility of the HOMP data analysis and was required to enable the implementation of some of the more complex events and measurements which had been specified.

Redesign of the collection of measurement data to improve the flexibility of what could be measured, including support for conditional measurements. This enabled the implementation of all the specified flight data measurements.

Implementation of a digital filter for use in derived parameter calculations. This enabled the implementation of a BHL-specified turbulence measurement based on multiple rapid collective control movements (see Section 5.4.1.4).

Incorporation of a facility within FDE for the manual allocation of severity levels to events, or for entering user defined equations for the automatic calculation of severity levels (see Section 5.4.3.9).

As an alternative to the above, addition of a capability to manually allocate event severity levels within FDT, and then export these to FDE (see Section 5.4.3.9).

Creation of the ability to export user defined information from FDT to FDE and to use this information for filtering and trending events within FDE. User defined information which was exported included; take-off type, landing type, flight type, base identification, number of passengers, pilot and co-pilot code numbers and any event severity levels which were manually allocated in FDT (see Section 5.4.3.2).

5.3.1.3 Compensation for aircraft system problems

Inclusion of a configurable airframe-specific correction to the transition of the ground-air logic to accurately locate the take-off point. This was required to compensate for a delay (which varied between aircraft) in the transition of the weight-on-wheels discrete from ground to air.

Improvements to the ‘bad data’ correction process, and preventing the processing of events on corrected data. The modifications were designed to overcome the “bad data” problems described in Section 5.2.1.

Provision of an ability to stop event processing a certain time before shutdown. Together with the above item, this prevented spurious events from being generated by stopping event processing prior to any reduction in main rotor speed prior to shutdown which caused some sensors or systems to go off-line.

Incorporation of a trap for any large numbers of events that were generated as a result of an aircraft sensor problem. An error log entry was created if the maximum number of events limit had been exceeded.

5.3.2 Experience with the HOMP software

The functionality of the FDT module improved dramatically during the operational phase of the trial and by the end of the trial it was very well matched to the HOMP requirements. Support from BA was very good, with nearly all the requests made for additional functionality being actioned.

Processing speed was satisfactory with a P3 550MHz computer and the program very rarely experienced any problems with individual data files during unattended bulk processing. Replay time was dependent on factors such as the size of the data file, the number of events and measurements implemented, the number of flight sectors contained in the file, and the number of events generated. The ‘worst case’ processing rate, with all the measurements implemented (including the additional flight profile measurements), was approximately 100x real time, i.e. 36 seconds to process 1 hour of flight data.

Configuration of derived parameters, events and measurements within FDT was considered to be something of a specialist task that required some initial training. With the introduction of a number of new software versions, the complexity of the FDT module increased somewhat during the trial.

The FDS simulation program proved to be very useful. It was used routinely for visualising flights for investigation purposes, and was a valuable aid for debriefing aircrew, either on the HOMP PC or remotely by sending data on a floppy disk.

By the end of the trial the FDE module had good functionality and was able to generate a range of useful trend charts, utilising new functions such as the importing of flight operations data. Little use was made of the facility to review the flight data associated with an event within FDE. Whilst necessary for a networked system in a large organisation such as BA, this was not found to be needed in the HOMP trial's single user system, where all investigations were carried out within FDT.

The BASIS FDM module was useful for routine analysis tasks such as the viewing of parameter histograms when adjusting event limits. However, MS Access and Excel were used to perform more sophisticated analyses. The module did not allow general browsing of the underlying measurements database, for example to determine the value of a particular measurement for a particular flight and, again, MS Access was used for this purpose. The link between FDT (where the measurements were made) and the FDM module had some limitations and did not allow, for example, re-scanning of a file if a problem was encountered during first scan process (e.g. no matching operations data). To allow the import of re-scanned data, the original data had first to be manually deleted from FDM using MS Access or Excel.

5.4 HOMP analysis

5.4.1 HOMP event analysis

The first project steering group meeting in January 1999 included a 'brain-storming' session to generate an initial specification of the helicopter events to be applied in the HOMP trial, based on a review of the following information:

a) The events used in the initial data analysis work reported in CAA Paper 97005 (Reference [8]).

b) The events used by BA on their B757 fleet.

c) The parameters recorded in the FDR data frame of BHL's Tiger helicopters.

d) A selection of helicopter operational occurrences extracted from an output from the CAA SDD database (Reference [10]).

A list of the helicopter events which were implemented in the HOMP trial is presented in Section 4.4.

5.4.1.1 Reduction of false and nuisance events

When the events and event limits initially specified were first applied an average of approximately 200 events were generated from each data file analysed. In a typical week of the trial approximately 5 significant events were generated from the processing of 50 data files. Therefore approximately 99.95% of the events generated at the start of the trial were classed as false or nuisance. During the commissioning phase as many as possible of the false events were eliminated and the number of nuisance events generated was also substantially reduced.

False and nuisance events continued to be reduced during the early part of the trial by the ongoing refinement of event definitions and limits, and also by improvements in the bad data detection and correction process. By the end of the trial, only about 90% of the events were classed as false/nuisance. Although this may still appear high, it equates to only one or two false/nuisance events per data file analysed. Approximately one third of the data files scanned generated no events and, of the rest, most had only two or three. There were also probably more significant events being generated at the end of the trial as a result of the development of better targeted event algorithms. When a trace generated a large number of events, this was normally either a training flight or the result of an FDR parameter defect, where there were usually multiple instances of the same event. It was necessary to filter out or eliminate such events to prevent these from distorting event statistics.

Some specific event problems and corrective actions are identified below:

- 08A/C (rate of descent): False events were triggered by a dip in pressure altitude values just before landing, due to the ground cushion effect. The problem was eventually cured by stopping event processing at a certain radio altimeter height above, pressure altitude difference from, and time before, landing. However, a number of nuisance 08A/08C events continued to be triggered, indicating a need to review and adjust the event limits. Modified limits were established using the database of flight data measurements, which substantially reduced the nuisance event rate. However, as a high rate of descent was not necessarily a safety issue and its significance depended on circumstances, some nuisance events had to be tolerated.
- 29A/B, 30A (pitch/roll attitude on ground): Events were triggered just before take-off due to a delay in the transition of the weight-on-wheels discrete from ground to air. The problem was overcome by including a configurable aircraft-specific timing correction for the weight-on-wheels transition (see Section 5.3.1.3).
- 29A/B, 30A, 34A/B/C (pitch/roll attitude and cyclic control on ground): Spurious events were generated during post flight engine washes when the main rotor speed was reduced and the alternators went off-line. A minimum main rotor speed condition was introduced together with a 'stop processing' condition to stop event processing before an engine wash (see Section 5.3.1.3).
- 35A/B (movement of deck): The deck motion severity index (MSI) limit was being triggered during taxiing at airports (the event was only relevant to floating platforms and vessels). An additional condition was introduced to only apply the event if the location was not an airport, as determined from the GPS lat/long data. The bad data checking process prevented the event from triggering if the GPS lost its configuration and could no longer identify an airport landing. A few MSI events continued to be triggered on decks, for example due to the fact that the helicopter was not sitting parallel to the deck. The limit applied to the MSI parameter was conservative as the event did not take wind speed into account, and MSI-based deck motion limits varied with this.

5.4.1.2 Review and refinement of events

After the first year of HOMP trial operations a review of the HOMP events was carried out to identify requirements for refinements, either by modifying the event logic (including the parameters used), or by changing the event trigger limits. A statistical analysis of the events which had been generated was used to identify both the events which were being triggered too frequently and also any events which were not being triggered at all. Where a requirement for changing an event limit was identified, the database of flight data measurements was used to help to set the new limit.

Of the 85 events implemented, 21 were modified following the review. A summary of these modifications is given below:

- 10 events had trigger limits increased to reduce their rate of occurrence (events were considered to be triggering inappropriately during normal operations).
- 1 event had the duration increased for which the event limit must be exceeded before it was triggered.
- 4 events were found not to be triggering. As a result, 3 events had trigger limits reduced to increase the likelihood of them being triggered. For 2 of the 3 events, the event logic was also modified. The remaining event was redefined using different parameters.
- 5 events had condition limits changed to modify the conditions under which the events were being tested for. 1 event had a new condition added.

During the review, the purpose of Event 20A (excessive heading change immediately after an offshore take-off) was questioned. The event was amended so that it was in accordance with BHL's Operations Manual which stated that, at night, a height of deck height plus 200 feet, and an airspeed of 70 knots, should be achieved before a turn is initiated.

In order to verify the correct operation of all events following configuration changes, or the release of a new version of the HOMP software, a set of test data known to trigger events was created. This data could be used to test that all events were working.

5.4.1.3 Allocation of severity levels to events

Whilst FDE automatically calculates severity indices for the fixed wing events in BA's SESMA programme, the calculations were not applicable to the helicopter events implemented in the HOMP trial. The nature of the helicopter events experienced suggested that calculating severity indices in a similar manner to those for fixed wing events would be difficult and inaccurate. There was not always a good correlation between helicopter event types and the operational occurrences detected, and the significance of events could be very dependent on environmental factors such as weather.

As a result of the above factors, for the HOMP trial it was necessary to manually allocate severity levels to events (see Section 5.3.1.2). BHL's HOMP Manager recommended that a numerical severity level between 0 and 10 be manually allocated to each event, and developed the prototype severity scale shown in Table 5.1 for this purpose.

Table 5.1 BHL's Event Severity Guide

Severity	Significance of Event
0	No significance
1	Contrary to operational or flight manual procedures or limits but no actual safety risk
2	Slight risk of problem if combined with several other factors
3	Risk of problem if combined with other factors
4	Slight risk of problem as a stand-alone event
5	Significant risk of problem as a stand-alone event
6	Serious risk of incident
7	Minor incident occurred
8	Moderate incident occurred
9	Major incident occurred
10	Accident occurred

The numbers in the severity scale were defined in terms of the potential erosion of helicopter operational safety margins and the same assessment criteria were applied to all events. Severities could be increased or decreased by one step to reflect a particularly serious or minor case of a particular category. Nuisance events were allocated a severity level of 0 to enable these to be separated from the genuine events within FDE.

Consideration was given to the allocation of severity levels to an occurrence that triggered multiple events of different types. One potential method would be to create a new user defined 'composite' event. The severity of the occurrence would then be assigned to this composite event and the component events would have severity levels allocated which are appropriate to each of them individually. A more robust approach would be to program a new event into the HOMP system based on the combined logic of the events which had triggered.

5.4.1.4 Future developments

Initial attempts to develop a 'turbulence' event based on either normal 'g' (sampled at 8Hz), or lateral 'g' (sampled at 4Hz) proved to be unsuccessful. The most important effects, however, are loss of lift and the pilot workload created by turbulence, which can potentially be detected by monitoring collective and cyclic control movements. For the HOMP trial, BHL implemented an 'uncalibrated' turbulence indicator based on the detection of multiple rapid collective movements using a high pass filter - rectify - low pass digital filter process (see Section 5.3.1.2). This was shown to correlate well with pilot submitted turbulence reports.

The CAA is developing a turbulence criterion for inclusion in CAP 437. The underlying assumptions for this work are that flight safety is inversely proportional pilot workload, and that pilot workload can be correlated with control activity. Earlier work using QinetiQ's Advanced Flight Simulator (AFS) at Bedford had demonstrated good correlation for a series of stylised military manoeuvres, and established a set of pilot workload predictors. The workload predictors are calculated from collective and cyclic control measurements and are calibrated to the Cooper-Harper rating scale for aircraft handling qualities. Since the nature of the task of stabilising a helicopter in a turbulent wind environment is fundamentally different to that of flying a manoeuvre, it had always been expected that a different set of predictors would be required. The original military-based workload predictors were, nevertheless, prototyped in the HOMP system with a limited degree of success. Further trials using the AFS have been undertaken to generate a new set of predictors tuned to the task of controlling the helicopter in the presence of turbulence. When available, these predictors are expected to provide a reliable and robust measure of pilot workload that can be related back to the turbulence criterion that is to appear in CAP 437. The data from these trials will also be used to calibrate the BHL turbulence indicator.

New HOMP events for monitoring operations in critical low airspeed regimes could be developed if an algorithm to accurately infer low airspeed information from other flight data parameters can be successfully produced and demonstrated (see Section 5.4.3.6).

5.4.2 HOMP measurement analysis

Once the event analysis was performing satisfactorily, attention turned to the flight data measurements. The final specification of the measurements to be implemented in the HOMP trial was agreed at a project steering group meeting in April 2000 (these are listed in Section 4.4). The functionality required to implement the measurements was provided with the release of version 1.4 of the HOMP software in July 2000 and all the specified measurements had been configured by September. Some further measurements were later added and, by the end of the trial, 140 different measurements were being made on each flight sector. A minor software update was required to provide an additional function for the calculation of two measurements needed to “map the helideck environment”, and this was accomplished in March 2001. By the end of October 2001 measurements from 5200 flight sectors had been stored in the FDM database.

The measurements proved useful when adjusting event thresholds as their mean values and variability gave an indication of normality. The event threshold could then be set to an appropriate number of standard deviations away from the mean. The measurement database could also be ‘mined’ to test hypotheses, or to support the investigation of event trends.

Additional measurements were added to gain information about the vertical profile of approaches flown during night operations to offshore helidecks. This information was used to assist in a CAA helideck lighting project to enable the lighting system specification to be optimised.

By the end of the trial a significant amount of data existed for the turbulence-generated pilot workload event. This could be plotted for a particular offshore installation, along with measured wind direction and strength on final approach, to give an indication of problem wind sectors at the location (i.e. mapping the helideck environment). With the limited number of participating aircraft, by the end of the trial the data for a particular installation was still limited, but with time the data sets will become better populated. However this data can only be used for fixed installations as the orientation of movable platforms varies with time.

At the end of the project, after the trial had been completed, ES-S implemented a further 150 offshore take-off and landing profile measurements and reprocessed one year of archived flight data with all 290 measurements applied. The measurement database produced included over 7,900 flight sectors.

5.4.3 **Information to support the HOMP analysis**

Early HOMP experience identified requirements for a number of additional items of information to support the data analysis process and aid the interpretation of events. This section summarises the key items of information identified.

5.4.3.1 Departure/arrival locations

It was necessary to identify the departure and arrival locations for all sectors flown; the large majority of these locations were offshore installations. BHL provided a locations table, identifying the names and latitude/longitude of all the airports and offshore installations to which they flew. This was used by FDT as a look-up table to automatically identify departure/arrival locations based on GPS data. As some of the offshore platforms were mobile, there was a need to keep the locations database up to date to enable these to be correctly identified. There would also be a need for time dependent database entries if old data is re-processed by FDT, but this was not implemented.

5.4.3.2 Flight operations information

Access to flight operations information such as aircraft take-off gross weight, number of passengers on board, type of flight (e.g. revenue, training, air test), base identification, and crew identities (suitably encrypted), was vital to the event interpretation and follow-up process. BHL provided a method of extracting the information from their Operations database. FDT was developed to import this operations data file, match it to the files of downloaded flight data, and utilise the operations data in the event analysis (see Section 5.3.1.2). Subsequent experience clearly demonstrated the value of this facility. Other modifications allowed the operations data to be exported to FDE along with event data in ‘user-defined fields’. The information could then be used for event filtering and trend analysis in FDE, for example, enabling training and test flights, or flights with no passengers, to be filtered out when producing event trend displays.

5.4.3.3 Weather information

Access to archived weather information was needed as there was often a weather factor in HOMP events. BHL stored all offshore installation weather reports in their Operations database. However it proved very difficult to obtain archived onshore weather data (Metars), so BHL produced a small program that automatically downloaded the Metars for selected airfields from the Met Office web site once per hour, and stored them in a database.

5.4.3.4 Day/night condition

In determining the significance of events, it was important to know whether these occurred in daylight or darkness, as there could be differences between day and night operating procedures. An algorithm was therefore implemented in FDT to enable a day/night flag to be set for any event generated (see Section 5.3.1.2).

5.4.3.5 Status indicator and notes field

To aid the process of reviewing scanned data files in FDT, a status indicator was added to the main browse list to show which files had been reviewed and a notes field was added to each record to allow notes on findings to be written and stored with the data files. These features proved to be very useful (see Section 5.3.1.2).

5.4.3.6 Low airspeed measurement

Although the HOMP trial event analysis proved to be very successful, a capability for low airspeed measurement would add significant value to the HOMP. The information could, for example, be used for new events related to time spent in the height-velocity diagram 'avoid areas', or proximity to a 'vortex ring' state, or for new measurements related to take-off and landing exposure times. However, fitting low airspeed sensors to all aircraft, then calibrating and maintaining them, would be expensive and impractical. A more feasible solution is to attempt to synthesise low airspeed from the existing FDR parameter set using artificial neural networks (ANNs) or other techniques. Westland Helicopters have been contracted by the CAA to attempt to develop and demonstrate a suitable algorithm. If the work proves successful, the low airspeed algorithm will be implemented in the HOMP analysis software in the form of a derived parameter at a future date.

5.4.3.7 Flight sectors data

FDE needed data on the total numbers of sectors flown to calculate event rates (i.e. events per 1,000 sectors flown) for trend analysis. This required a separate process to generate a sectors file from BHL's Operations database and import it into FDE. To eliminate the requirement, FDT could automatically generate flight sectors data and export this to FDE with the event information (to calculate events per 1,000 sectors analysed), however this was not implemented during the trial.

It was also useful to monitor the data collection rate from the HOMP aircraft, i.e. processed versus actual flights. This information could be used to maximise the data collection rate and give early warning of poor performance, either of the project in general, or of one particular operation or aircraft. This was not implemented within FDT, but BHL produced a small program that listed any flights on their Operations database that had not been processed by HOMP. The program could also automatically generate a percentage data collection rate between two given dates.

5.4.3.8 Raw data associated with an event

Once an event was imported to FDE, it would have been necessary to be able to review the raw data associated with it if severity levels were to be allocated within this module. There was no common reference number in FDE and FDT which could be used to identify the relevant FDT file associated with an event in FDE and, after a certain period of time, the original file may have been deleted or archived. Although not an issue for the HOMP trial, the potential difficulty was overcome with the introduction of FDV, which enabled cut sections of a trace associated with an event to be accessed directly from FDE.

5.4.3.9 Event severity levels

To perform meaningful event trend analysis it was necessary to allocate severity levels to events so that trends of cumulative severity levels, rather than simple event numbers, could be produced. For the HOMP trial the only feasible option was to manually allocate these severity levels. Modifications enabled a numerical severity level of between 0 to 10 to be allocated to each event within FDT, and then exported to FDE (see Sections 5.3.1.2 and 5.4.1.3).

5.4.3.10 Analysis configuration control

Configuration control is an important aspect of the HOMP analysis. Whilst it could be performed manually, ideally facilities should be provided for automatically recording configuration changes and identifying any relevant changes during trend analysis. FDT maintained a log of changes to event definitions and limits, however no information on limit changes was exported to FDE, and FDE could not identify that changes had taken place when displaying trends of events in different time periods. A replay version number and date could be incremented when events are changed, and then exported for the annotation of event trend plots in FDE, however this was not implemented.

5.5 HOMP operational and management experience

5.5.1 Programme workload, resources and facilities

Workload was high during the early stages of the trial as a result of having to process the incoming data whilst also managing changes to the system (bug fixes, event refinements etc.). Workload soon eased for routine download and analysis, with routine programme tasks typically taking about one hour per day. However, without an assistant, work could quickly accumulate during periods of leave etc. Investigating significant HOMP events could be time consuming, as could various other duties such as producing newsletters, or analysing BASIS FDE and FDM data. Workload is, to some extent, a matter of choice – but the more time allocated to the programme, the greater the benefits that are likely to accrue.

The trial confirmed that starting with a small number of aircraft was the correct approach, as this enabled events and procedures to be refined before the commencement of any large scale data gathering. It is essential to reduce false event occurrence rates to a low level at an early stage to avoid being overwhelmed by them. Once this had been achieved, the trial identified no major obstacles to a large scale implementation.

A recurrent problem faced by the HOMP Manager was the conflict between flying duties and the requirements of running the programme. The conflict arose because, in order to maintain the HOMP’s credibility with aircrew, it was necessary to use a qualified pilot to manage the programme. However, such personnel are expensive and the exact number required to fulfil a charter company’s contractual obligations is difficult to predict, whilst there is a long lead time in training new personnel. When there was an upturn in flying activity, Operations management were naturally reluctant to agree time off flying duties if the HOMP Manager was needed to meet the company’s contractual flight requirements. It is difficult to suggest a solution to this problem, but it is probably the most significant issue likely to prevent a programme from being effective or, in an extreme case, to cause the programme to fail. It is probably the case that the smaller a company, the more prevalent this problem will be and, to ensure the HOMP’s effectiveness, a workable solution must be found. This might be to involve additional personnel in the programme so that backup can be provided for the HOMP Manager when necessary, or to contract out some routine tasks.

The trial demonstrated the importance of having appropriate office facilities for the programme. Because of the sensitive nature of information held it is essential that adequate security is provided for the HOMP computer and any associated paper records. Facilities must also be provided for confidential phone calls and debriefs. The location of these should ideally be reasonably close to the flight planning area but not so close that crews can readily be seen entering and leaving by other pilots, or that conversations are likely to be overheard.

5.5.2 Programme agreements

For the trial no formal agreement was put in place between the company and the aircrew, but a “statement of intent” was published by the HOMP Manager. Prior to a fleet-wide implementation it will be necessary to have an agreement between management and aircrew, specifying how HOMP data can be used, and no obstacles to this were identified.

Where, in an airline such as BA, aircrew are fully unionised, the best approach is to implement a written agreement between the company management and the aircrew union (i.e. BALPA). BHL had only a limited relationship with BALPA, and a significant minority of the company's pilots were not members of the union. Therefore, in this case, BALPA could not be used to fulfil the same representative role as in BA. However, as a result of a combination of their flight data monitoring experiences at BA and BHL's non-punitive management philosophy, BALPA were very supportive of the introduction of the HOMP.

To ensure that there was no inappropriate access to, or misuse of, any of the flight data obtained during the trial, confidentiality agreements were drawn up between BHL, Shell Aircraft and the CAA. The agreement with the CAA was based on their existing confidentiality agreement with BA. A non-disclosure agreement was also put in place between BHL and ES-S.

BHL's relationship with its customers is very different from that of an airline, as these are almost exclusively large oil companies which have their own aviation departments. This results in a much closer relationship with the customer on technical and safety issues than would be the case with an airline, and hence a higher probability of a customer expecting to have access to any sensitive HOMP-derived data. For a full scale HOMP implementation, contracts and confidentiality agreements may require modifying so that all parties are clear on the requirement to maintain confidentiality. In particular, operators may need to include clauses in contracts with their charterers that specifically preclude the release of any HOMP data to them, except with the permission of all members of the flight crew. However, a charterer may wish to specify a safety measure derived from the data as a quality check.

5.5.3 Programme operation and management

The HOMP trial raised a number of operational issues for which there was no clear guidance to the crew, and it was necessary to decide whether any problem existed and, if so, whether additional guidance should be introduced. Whilst it was clearly beneficial to raise these issues for discussion, when considering changes to an already safe system (i.e. helicopter transport), it was necessary to be careful not to take action which could ultimately reduce overall safety in some subtle way. For example if, because of the HOMP, crews felt unable to use the full flight envelope of the aircraft when no passengers were carried, over time their experience of this envelope would diminish. In an emergency, their response may then be affected as a result of operating outside their personal flight envelope, and the likelihood of a safe outcome could be reduced.

For the trial, BHL did not formally include the HOMP in their safety management process (this will happen as part of a full scale implementation of the programme). However, the HOMP Manager held meetings with training and safety staff to discuss certain incidents and, in some cases, action was taken to modify procedures. The responsibility for carrying out these actions lay with management and training staff, with the HOMP Manager's role being to provide recommendations.

The HOMP was highly successful at detecting a variety of potential safety issues. Sometimes these related to individuals or to procedures, but the HOMP was also a powerful tool for detecting general issues with a particular operation. However, detection of a safety issue is only the first step, remedial action may then need to be taken and this can be much more challenging, especially if it relates to human factors and cultural differences. For example, there is a unique culture associated with small satellite bases which appears to be common throughout the aviation industry. These satellite bases can have the view that procedures are too rigorously applied at the main base, and may consider themselves to operate more efficiently. There may be a belief at these bases that it is better to do things differently, however this can result in more mistakes being made. Tackling such cultural issues is very difficult as they will probably have been present for many years and a heavy-handed approach is unlikely to succeed. The best solution is a gradual inculcation of attitudes. This will be more easily achieved once the HOMP is fully implemented.

The trial highlighted the importance of the HOMP Manager's role in achieving a successful programme. The HOMP must be run by an experienced pilot rather than a non-pilot manager. Whilst pilots are likely to be receptive to observations from their peers, they would not accept suggestions from personnel with no flying experience. The HOMP Manager must have a high degree of integrity and be trusted by his fellow pilots. Robust confidentiality is essential, and management must allow him a degree of independence and rely on his judgement as to what action, up to removal of anonymity, is appropriate. A HOMP must not be seen as a punitive management tool – it cannot function without the co-operation of the pilots. Management must, however, give the HOMP Manager every support, including making time available from flying duties and listening to his concerns on operational issues.

5.5.4 Feedback to aircrew

Obtaining a good response from aircrew to the HOMP was an important element of the trial. Aircrew are aware that they will be the natural focus of attention if anything goes wrong, and so can be understandably defensive. It is therefore important to demonstrate to aircrew that the programme has some benefits to offer them. If their first encounter with HOMP is to receive a reprimand, they will naturally resent it. Therefore an initially low key approach to aircrew feedback was essential to build trust. Aircrew response was good once their initial fears were allayed. Generally, those who were contacted after significant events were either receptive to the HOMP Manager's comments or, in several cases, very pleased to find out what had gone wrong, or that the circumstances had come to light.

Whilst face to face communications with aircrew at the main base worked well, it proved to be difficult to achieve good communication with crews at the remote base (for example by telephone), so dealing sensitively with issues there was much harder. One possible solution would be to have trusted representatives at remote bases who could be called upon to deal with any local issues.

One of the few communications difficulties experienced occurred when providing feedback to aircrew located at Scatsta (i.e. the remote base). With the few days delay in receiving the downloaded flight data from the Scatsta aircraft, by the time the HOMP Manager attempted to make contact the co-pilot had already left the base for a period of 2 weeks off duty, and was out of the country. The captain was still on the base, but he disagreed with the HOMP Manager's observations on the flight. The HOMP Manager sent the captain an extract of flight data on floppy disk for him to replay, with an accompanying letter indicating that the information was confidential between the captain, the co-pilot and himself. The captain, however, showed the data to a number of his colleagues on the base. The HOMP Manager was unable to contact the co-pilot until after he returned to the operation and had heard about the event from his colleagues in the crew room. Fortunately he was very understanding, but it could have been very damaging to the project. The lesson learned from this experience is never to discuss events or send evidence to only one of the crew - it should be both or neither.

Another feedback difficulty occurred when it was necessary to bring an event to the attention of a long-serving pilot who was not well known to the HOMP Manager. He was defensive and could not be persuaded that the event indicated poor airmanship. Despite a difficult meeting, there was no subsequent recurrence of the episode. Although the option of identifying the individual to management was considered, it was concluded that the best approach was to wait to see whether the meeting had the desired effect, and in this case it had.

Apart from these two difficulties, crew reaction to individual feedback from the HOMP Manager was either neutral or appreciative. The aircrews growing trust in the programme was demonstrated by the increasing number of pilots who visited the HOMP office to enquire about aspects of their flights.

One of the key objectives of a programme is to ensure good communication of the lessons learnt to all crews. Probably the best vehicle for this is a periodic newsletter. As well as recounting the lessons learnt from specific incidents, trend information can be promulgated for all to be aware of. Many pilots commented on the usefulness of the HOMP newsletters that were published during the trial.

5.5.5 Feedback to training

HOMP data obtained from line flights was used to provide beneficial feedback to training. For example, the ongoing triggering of an event related to the risk of a rollover during taxiing led to a memo, with supporting HOMP graphs, being sent to all training captains. This reminded them of the importance of imparting knowledge of the potential pitfalls, and correct technique, of taxiing the Super Puma during initial and recurrent training, and if appropriate during normal line flying.

There were cases where, after experiencing difficulties flying an ILS approach, crews were able to view the flight replay to identify where things started to go wrong and why. This culminated in an FDS replay floppy disk being sent to all training captains, showing some commonly-found poor techniques, with accompanying notes explaining the issues and suggesting better methods.

Inexperienced pilots tend to over-control during periods of stress, such as offshore landings. One of the most difficult aspects of trying to prevent this is a lack of willingness on their part to accept that they are doing it. Having obtained the pilots permission, another example of the use of HOMP data for training was to compare control position data recorded on their flight with an approach and landing flown by a line-training captain, and highlight the difference.

5.5.6 Feedback to engineering

Flight data monitoring has provided engineering benefits to fixed-wing operators and, in time, the same is expected to be true for helicopter operators. The helicopters involved in the HOMP trial were all equipped with HUM systems and during the trial there was only limited engineering interest in the additional information which could be provided by the HOMP. However, there was evidence of a gradual change in attitudes, and it is recognised that it took several years for line engineers to fully appreciate the benefits of HUMS.

5.5.7 Managing the data analysis

The trial highlighted the importance of identifying all the information required to support the HOMP process before embarking on a full-scale programme. For example, in order to draw conclusions from the flight data, the analyser must be in possession of all the relevant facts, which can include operational and weather information.

When specifying the HOMP events and flight data measurements, the importance of understanding what these are trying to achieve was recognised, and one of the objectives of the trial was to clarify this. Before specifying an event it is necessary to consider what action will be taken when it is triggered. If the answer is “none”, then perhaps the event should not be included. However, it may be appropriate to leave in events which simply act as markers to particular types of flying, but are not necessarily indicative of a problem, providing the necessary steps are taken to filter these out of any statistical safety analysis.

At the commencement of the trial, there were some concerns that helicopter operations would be too difficult to define and monitor automatically, however the trial experience proved that these concerns were unfounded. Helicopter operations are undoubtedly more difficult to automatically monitor than fixed-wing but, nevertheless, a reasonable degree of automation was achieved in the event detection. The event thresholds were often set relatively low because experience showed that the triggering of an event could be a pointer to something more significant which had not been foreseen. However this did not result in a high number of nuisance events.

Considerable interpretation could be required to determine whether events were worth acting upon. The main advantage of helicopters is that they are more flexible than their fixed-wing counterparts, but this can increase the difficulty of creating algorithms that define good or bad operating practice. However, although probably less than for helicopters, fixed wing events still need considerable manual verification and interpretation. It may be possible to gradually increase the complexity of the HOMP events to reduce nuisance triggering levels in a full scale programme. However, the more parameters that are included in an event definition, the more opportunities there are for it to fail to trigger.

The HOMP trial experience showed that the one or two more significant occurrences which were detected were not well defined by the specific HOMP events triggered on the flight. A relatively major occurrence could be indicated by one or more seemingly minor events, with the significance of the occurrence only becoming apparent when the data associated with the events was reviewed. In addition, the degree of significance of an event could be very dependent on circumstances. It was therefore difficult to devise events specifically targeted at these major occurrences and, even then, an event could only be devised if its occurrence had been foreseen.

The number of unexpected occurrences detected during the trial highlighted the fact that it was not possible to foresee all the different types of occurrence that could be monitored. The ability of events to identify occurrences which had not been envisaged when they were implemented was shown to be a strength of the HOMP. Once unexpected occurrences have been identified it is usually possible to implement new events which are targeted at them. Where this is not possible, the process can continue to rely on the detection of the event by circumstance and peripheral events, and a “user defined” event could be manually created in the FDE module to enable it to be tracked.

The trial demonstrated how the analysis of event trends (with the FDE module) could provide a useful input to the safety management process. Whilst the trend information had little relevance to the few major “one-off” occurrences, a key benefit of the trend analysis was its ability to bring attention to the cumulative risk from more frequently occurring, but less individually significant, events. The relatively high proportion of nuisance events did not distort trends as they were allocated severity levels of zero and were filtered out.

A number of changes to event definitions and limits were made at different times during the trial, primarily to reduce the occurrence of nuisance events. It is important to document these changes as they will affect event trends.

5.5.8 Allocation of severity levels to events

Severity levels were assigned to events reviewed in the FDT module using the severity guide shown in Table 5.1 in section 5.4.1.3. These were then exported with the events to the FDE module.

Manual allocation of severity does create the possibility of human error or bias affecting event trends, but with a range of 10 steps an error of one step or so is not likely to be statistically significant. In a small company, the allocation is likely to be performed by only one or two personnel and therefore it should be possible to achieve adequate consistency.

There may be scope for the automatic calculation of severity levels for some events as is performed by BA. However, the value of this will be reduced because the flexibility of helicopter operations makes it difficult to define algorithms that can automatically detect flight safety issues, and circumstances and external factors such as weather can also be significant. Those events that were simply flight manual exceedances, for example VNE or bank angle exceedances, were generally allocated a severity value of 1 (limits were not exceeded by a large margin). A default value could automatically be assigned to an event, which could then be modified if required during the event review process. This was not implemented in the HOMP trial, but could be developed in the future as more experience is gained.

During the trial, the majority of events were assigned a severity value of zero. This reflected the desire to leave in events which were not really significant in themselves, but which might point to some other occurrence not previously foreseen.

Section 6 HOMP Trial Results - Flight Data Events

6.1 Individual events

The HOMP event analysis produced significant results which clearly demonstrated that the programme enhances operational safety. A number of examples of individual HOMP events are described below, the results of the event trend analysis are then described in Section 6.2.

The example HOMP events include three that were reported by pilots (items 6.1.17, 6.1.18 and 6.1.19). A HOMP involves more that just the detection of events from flight data, it is the whole system of problem detection and correction. In these cases the programme provided the facility for pilots to report a problem and to have it investigated confidentially with the HOMP system. Without HOMP, event 6.1.19 may not have been reported, and 6.1.17 and 6.1.18 may only have resulted in a tech-log entry. With no supporting evidence, tech-log entries relating to transient defects which cannot be confirmed on the ground often result in clearance by "tested on the ground – no fault found – released to service". It is also part of the HOMP process to detect occurrences by any means and then, if appropriate, create new events specifically targeted at them.

6.1.1 Take-off with full right pedal

HOMP events triggered	
Event No	Title
07A	High roll rate below 500 ft AGL
34B	Excessive rate of movement of longitudinal cyclic on ground
38B	Taxi limit (right gear lifts)

The most significant finding of the trial related to an incident involving a take-off with full right pedal, which the HOMP detected. It was the co-pilot's sector as pilot flying. During lift-off from a platform, the aircraft yawed violently right, with associated rolling and pitching, as the co-pilot regained control. The helideck crew were concerned and made radio contact to check whether there was a problem. The aircrew did not understand what had happened. The captain believed that the co-pilot must have raised the collective too quickly, instead of stabilising the aircraft when it was light on its wheels. As a result, the co-pilot suffered a loss of confidence, and fully appreciated the HOMP Manager's subsequent debrief on the exact cause of the incident, as he was then empowered with the knowledge required to prevent a recurrence.

The HOMP system showed that, after the autopilot had been engaged at the end of the rotors running turn-round, there was a two minute delay during which there were two radio transmissions, implying some distractions. During this time there was a progressive change in apparent aircraft heading to the left caused by gyro-compass precession. When this reached 2° left the autopilot, trying to maintain heading, started to gradually apply right pedal. Full right pedal was achieved after another 30 seconds. The only cockpit cues were a torque indication of 25% (14% would be normal) and 2° left roll attitude. The co-pilot then started to raise the collective to lift off. At 11.5° collective pitch he started to reduce the tail rotor pedal but, almost simultaneously, the aircraft yawed 30° right (probably with tyres still in light contact with the deck). A shaky hover was established. In the debriefing the co-pilot reported that, when putting his feet on the pedals, he had thought that they were in an abnormal position, but assumed that this was their position at landing (the captain had carried out the landing). He did not have sufficient confidence to make a large change in pedal position before starting to lift off.

Figure 6.1 shows the position of the tail-rotor pedals and collective, and the status of the autopilot, during the period on deck. It is apparent that no-one had their feet on the pedals during the period in question. Although not shown on this graph, the cyclic had also moved slowly to the right in an attempt to compensate for the left roll induced by the tail-rotor. The total movement was only about 20% of travel, but it again appears that no-one was holding the cyclic.

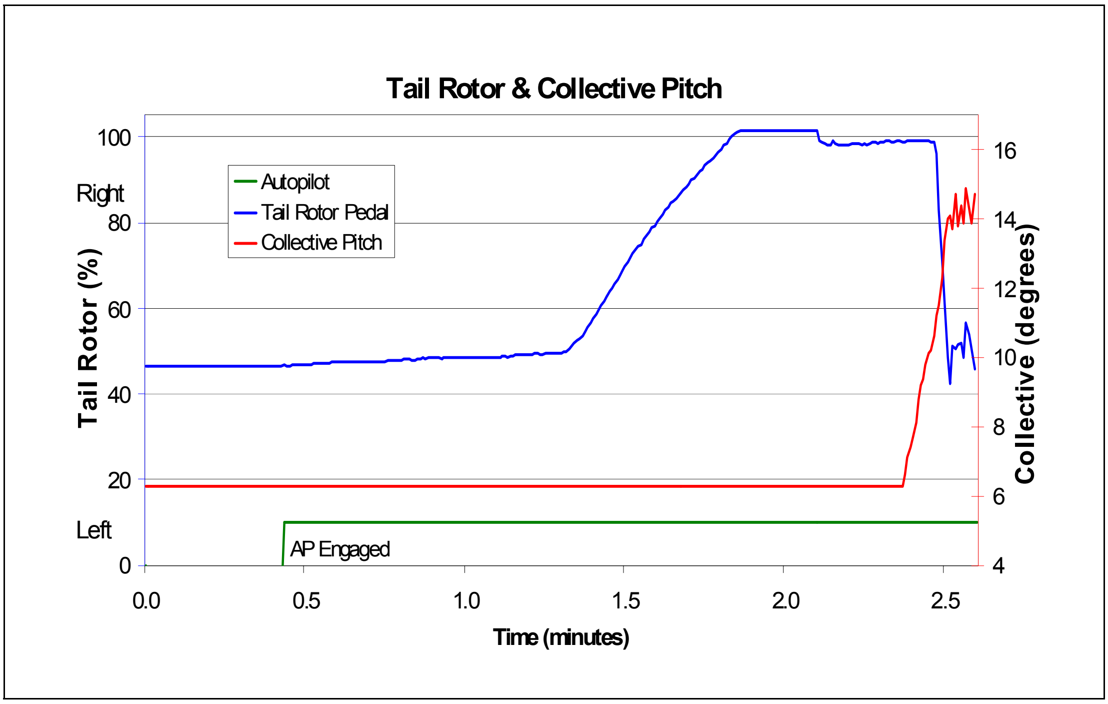


Figure 6.1 Tail Rotor, Collective Pitch and Autopilot vs Time

The HOMP system was used to debrief the crew as to the real cause of the problem, and to provide positive feedback to prevent a repeat occurrence. The event was considered to be significant as, in the mid-80s, a Super-Puma was destroyed when the crew lifted off with full left pedal and rolled over on a training flight. The instructor was demonstrating how the aircraft could be lifted off with feet off the pedals but, unknown to him, the autopilot had applied full left pedal prior to lift-off. In addition, a BHL Tiger rolled over during taxiing because a large amount of right pedal was applied with insufficient right cyclic.

The HOMP subsequently detected a second occurrence in which the autopilot applied full right pedal prior to an offshore take-off. After the autopilot had been engaged the crew were again distracted by radio traffic and other tasks, during which time the autopilot moved the tail rotor pedals to the full right position. The co-pilot then placed his feet on the pedals and, detecting the problem, disengaged the autopilot, centred the pedals, and re-engaged the autopilot. The co-pilot did not discuss the occurrence with the captain, who remained unaware of it until contacted by the HOMP Manager. The HOMP Manager publicised the occurrence and briefed the line training captains on it, highlighting the fact that the controls were not being monitored.

6.1.2 Autopilot engaged after landing

HOMP events triggered	
Event No	Title
34A	Excessive longitudinal cyclic control with insufficient collective pitch on ground

The autopilot had not been disconnected after a landing on an offshore platform and neither of the aircrew were guarding the controls. As a consequence, the cyclic control motored forward and right until this was at 75% of full forward travel and the rotor blades hit the flap restrainers. Probably on feeling the vibration, the pilot pulled back the cyclic and disengaged the autopilot. As a result of the occurrence, two new events were created to detect instances in which the autopilot remained engaged beyond a certain time after landing and before take-off.

Following a flight from Scatsta, the HOMP detected another occurrence of the autopilot being left in after landing. This caused the cyclic to motor forward for about one minute, at which point the rotor presumably hit the flapping restrainers. The data file stopped about 3 seconds later. The HOMP Manager contacted the pilot, who admitted that the CQAR card had been removed at this time.

There were a number of other occurrences of the autopilot being left engaged after landing. One was at Aberdeen, where the autopilot remained engaged whilst passengers left the aircraft, and was only disengaged at the time of the crew change. Generally, these occurrences showed that the post flight checks were not being properly completed, and also indicated a failure to comply with an Operations Manual requirement that whilst one pilot is occupied with other tasks, the other must be guarding the controls.

6.1.3 Inadvertent loss of airspeed

HOMP events triggered	
Event No	Title
03B	High pitch rate above 500 ft AGL

During the return to an airfield from offshore, the weather was deteriorating. The co-pilot (who was the pilot flying) proposed making an instrument approach but, despite the heavy rain showers, the captain wanted to make a visual approach. The crew decided at a late stage that the weather was too poor to continue, and the co-pilot initiated a climb shortly before crossing the coast in order to make an instrument approach. During the climb, airspeed was generally low and at one point reduced to 30 kts. Figure 6.2 presents a trace view of the event (showing radio altitude, airspeed, pitch attitude and collective position). The captain failed to monitor or prompt during this time, which is the primary duty of the pilot not flying. Probably in response to a very late prompt, the co-pilot then rapidly lowered the nose, and the climb was continued at 70 kts, which is the minimum recommended climbing speed in IMC. Airspeed had been below 70 kts for approximately one minute. The captain was probably busy arranging the IFR approach, hence the delay in monitoring and prompting. The co-pilot was concerned about the proximity of the terrain and was attempting to climb at best angle of climb speed (45 kts), although this was well outside the Flight Manual IMC flight envelope.

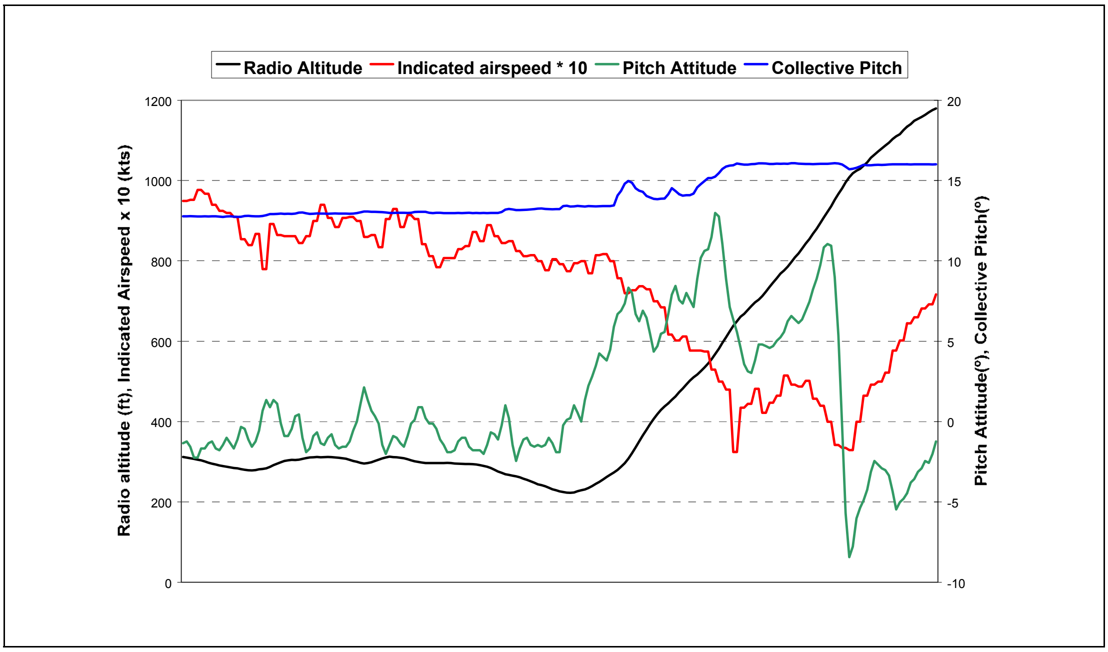


Figure 6.2 Trace View Showing Loss of Airspeed During Climb

Figure 6.3 presents a snapshot from FDS at a point during the climb. The plot at the right of the screen shows a plan view of the flight profile and the plot at the bottom right shows a profile view (the aircraft is positioned at the point where the flight profile changes from green to magenta). The terrain is shown in orange at the bottom of the profile view. The vertical speed indicator (bottom left) is showing a 1500 fpm rate of climb and the airspeed indicator (top, right of centre) is showing that the airspeed is below 40 kts.

Figure 6.3 FDS View Showing Loss of Airspeed During Climb

Although a helicopter cannot stall at low airspeed, the drag curve is very steep and control can easily be lost in IMC. The dangers of low airspeed had been highlighted by a previous serious incident on another type. Following a go-around from an offshore installation at night, the crew decided to climb at low airspeed but, due to extreme turbulence, they failed to notice that airspeed had fallen below zero. They lost control of the aircraft at about 1,000 feet and developed a 6,000 feet/minute descent rate, pulling out of the dive at 75 feet above the sea. The co-pilot involved in the HOMP event had joined the company since that incident and the training system had possibly failed to make him aware of the lessons learnt. The co-pilot was receptive to the HOMP Manager’s points and appreciated the opportunity to discuss the related CRM issues. Whilst the captain was less receptive to the comments made, the feedback hopefully made him think about the issues discussed.

6.1.4 Deck out of limits

HOMP events triggered	
Event No	Title
30A	High roll attitude on ground

Prior to landing on a vessel, the pilot had been informed that deck pitch and roll was ±1.98 degrees (landing limit = ±2 degrees), however after landing he believed that the actual pitch and roll was much greater than this. The pilot therefore requested a printout of the HOMP data. This showed aircraft roll angles of up to +4 and -6 degrees (Figure 6.4). The pilot's request had been made before the HOMP data had been processed and the system subsequently detected a number of 'roll attitude on-ground' events. Unfortunately the calculated Motion Severity Index values were incorrect owing to a faulty output from the aircraft's longitudinal accelerometer.

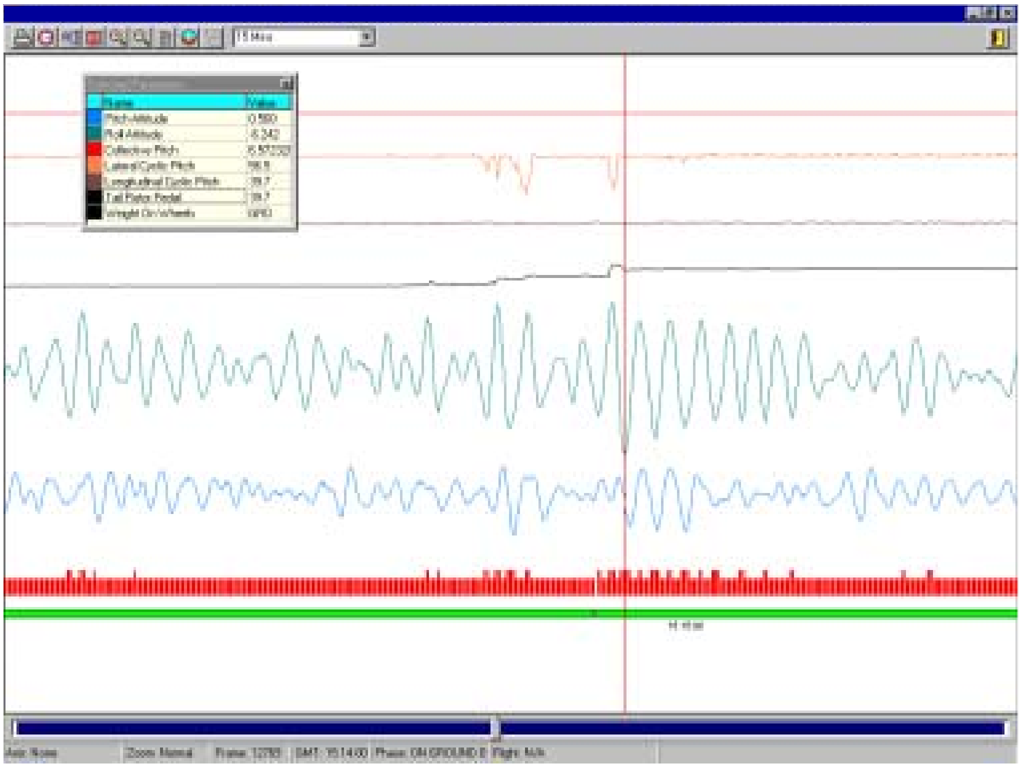


Figure 6.4 Pitch and Roll on Deck

There were a number of occurrences of pilots requesting HOMP traces following landings on vessels where they believed that the deck pitch, roll or heave was out of limits. For example, in another case the aircrew had raised an ASR after landing on a vessel as they believed that the deck was grossly out of limits. The HOMP subsequently generated MSI and roll events, with the data showing a maximum roll angle of 5.6 degrees. Pilots have given the HOMP traces to the Fleet Manager for forwarding to the vessel's operators. By raising awareness of the importance of accurate figures, reported deck motion figures should become more reliable. If no improvement is seen, the HOMP has provided BHL with the evidence to support further action, which could ultimately include refusing to operate to a specific vessel.

6.1.5 Aircraft hit by a line squall on an offshore platform

HOMP events triggered	
Event No	Title
35A	Excessive movement of deck (Motion Severity Index)

The HOMP Manager received a request from an engineer for some HOMP information when a pilot made an entry in the tech log after a line squall had hit his aircraft when it was on the Fulmar platform. The wind changed from 20 kts on the nose to 70 kts on the beam, resulting in abnormal noises from the landing gear and the helicopter shuffling on the deck (an ASR was raised). When the flight data was replayed the incident was detected by the HOMP, with a deck Motion Severity Index event being generated whilst the aircraft was on the platform, which was a fixed installation. The incident is an example of how events triggering in seemingly inappropriate circumstances can identify unexpected occurrences.

By being able to detect and measure weather related effects, the HOMP can help to ensure that aircraft and crews are well prepared for any poor weather. The line squall event shows the importance of having the aircraft properly chocked on deck (something which crews can become complacent about), and of maintaining deck friction by ensuring nets and non-slip paint surfaces are clean and in good condition.

6.1.6 Go-around following an offshore Airborne Radar Approach (ARA)

HOMP events triggered	
Event No	Title
40A	Torque split in the cruise

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.

This is another example of a HOMP event leading to an unexpected finding. Following the discovery of the go-around incident, 3 new events were created to detect a go-around, and also to detect descent below different height limits in daylight and at night during the go-around.

6.1.7 Below minimum descent height during offshore Airborne Radar Approach (ARA)

HOMP events triggered	
Event No	Title
41B	Below minimum descent height on go-around

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. Figure 6.5 presents a snapshot from FDS taken during the approach, with the radar altimeter showing a height of 170 feet.

Figure 6.5 FDS View During an Airborne Radar Approach

Following a second occurrence of an approach being flown well below minimum descent height, the issue was highlighted in a HOMP newsletter. Airborne Radar Approaches to offshore installations carry a potential risk but, by monitoring the approaches with a HOMP, any poor technique or exceedance of limits can be detected and remedial action taken to ensure that the risk is minimised.

6.1.8 Below minimum en-route height

HOMP events triggered	
Event No	Title
22B	IAS greater than 100 knots below 100 feet AGL with gear selected up

After departing and climbing to 600 feet, the pilot flew over an island. When flying over a hill on the island (which has a significant bird population), the aircraft's height was only 58 feet AGL (Figure 6.6). The Operations Manual specifies a minimum en-route height of 500 ft. The HOMP Manager showed the pilot an FDS trace of the event and reminded him of the correct procedures. However the pilot did not accept that the matter was a flight safety issue. The HOMP Manager was unsure as to what to do next, however the pilot subsequently identified himself to the Head of Flight Operations and to some of his colleagues. The HOMP Manager was therefore able to discuss the issue with the Chief Pilot. If a similar situation arose in the future, the HOMP Manager would involve the Flight Safety Officer in the follow-up process as an independent arbiter.

Figure 6.6 FDS View Showing Flight Over Island

6.1.9 Take-off with cabin heater on

HOMP events triggered	
Event No	Title
19A	Heater on during take-off

The HOMP showed that during the winter period 1999 - 2000, on average, one aircraft a week was taking off from off-shore with the cabin heater on. No doubt the heater was applied on deck for passenger and crew comfort and possibly demisting but, apart from being prohibited in the Flight Manual, when the heater is on during take-off, the maximum available power is reduced and the power turbine inlet temperature for a given power is increased. In the event of an engine failure, having the heater on could make the difference between ditching and flying away.

A newsletter was issued drawing this to the aircrew's attention. During the winter of 2000-2001 there were relatively few such events so it was decided not to include this item in the already long pre-take-off checklist.

6.1.10 Taxiing in rollover zone

HOMP events triggered	
Event No	Title
38B	Taxi limit (right gear lifts)

When taxiing a Super Puma it is possible to induce a rollover by applying excessive right pedal without applying sufficient right cyclic to counteract the rolling couple. BHL had an aircraft rollover in dispersal some years ago, and since then this aspect of its ground handling has been of concern to the company. The HOMP system generated several 'rollover limit' events during taxiing.

In one case, the co-pilot was in the right-hand seat on his first line flight following a right-hand seat conversion, and so was unused to taxiing the aircraft (there are no toe-brakes on the left, so aircraft are never taxied from the left-hand side). When contacted after the event, the captain reported he had been aware that the co-pilot had been close to the rollover zone and, although he had prompted, there was a short delay before a correction was applied. As the captain was a training captain he agreed to discuss the topic with the co-pilot again to highlight the potential dangers.

In another case, the controls were placed in very similar positions to those in the previous accident which, had the aircraft not been heavy and hence had a low vertical centre of gravity, could have resulted in a rollover. Although the handling pilot was an experienced captain, he had recently converted from another type. The follow-up revealed that the pilot involved was not fully aware of the rollover problem and, whilst the subject was covered in the type conversion, its significance had not been recognised. As a result, the Chief Training Captain issued a memo to all training captains reinforcing the need to highlight this issue on initial and recurrent training.

A graph of lateral cyclic and yaw pedal positions (Figure 6.7) was sent to the crew and provided useful debriefing material. The red line in Figure 6.7 is the edge of the zone defined by Eurocopter in which the combination of lateral cyclic and yaw pedal position might cause rollover. The pink joined-up points show the actual data from the accident on BHL Tiger G-TIGT as it was rolling over, and the blue points are taken from the HOMP event which had been triggered. Not shown is the roll attitude, which was approximately 3 degrees left, confirming the proximity to a rollover.

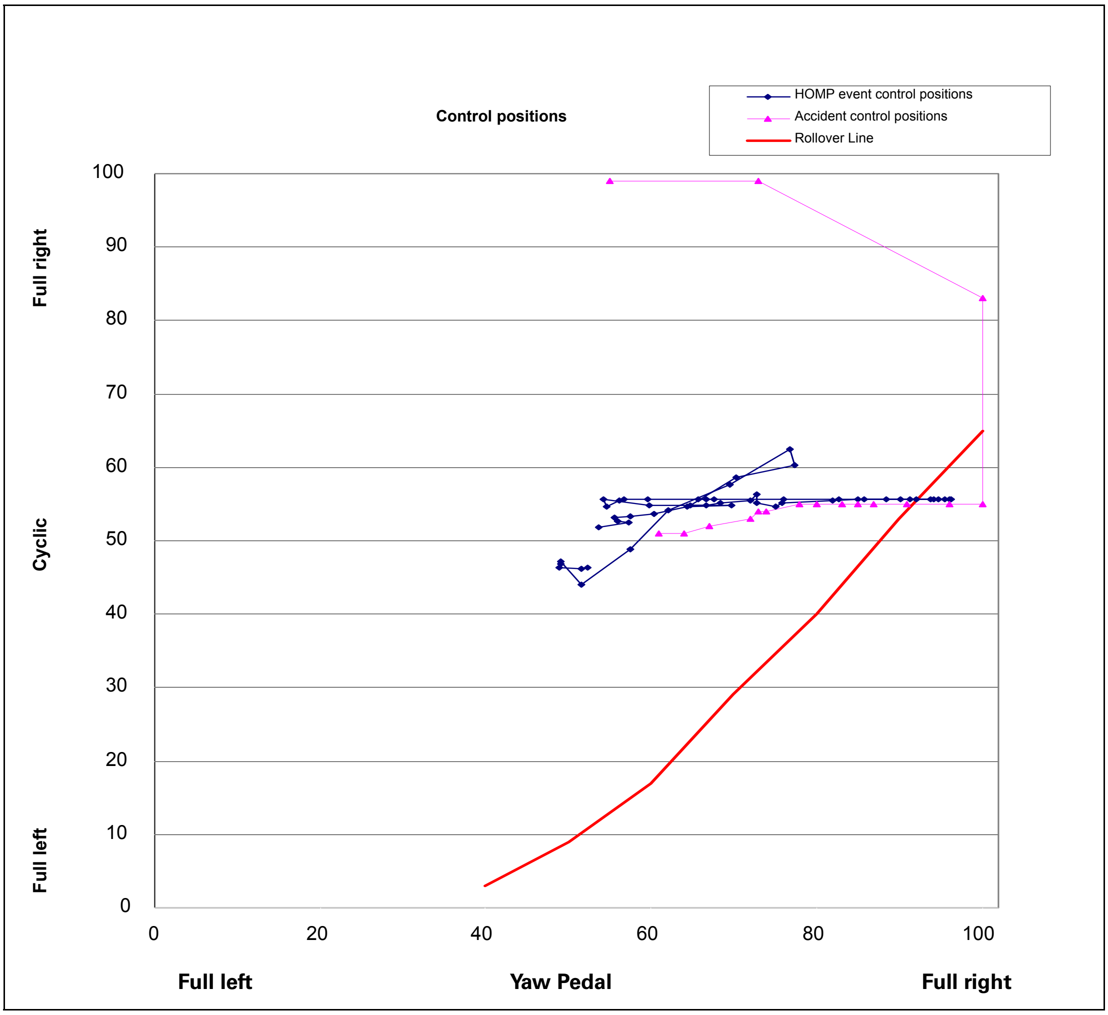


Figure 6.7 Lateral Cyclic and Yaw Pedal

6.1.11 Flight through hot gas

HOMP events triggered	
Event No	Title
28A	Flight through hot gas

A number of 'flight through hot gas' events were detected, with temperature rises of 5 to 12 ^{o}C in 3 or 4 seconds. The majority of these occurred on the Ninian Central where there are known problems with the platform's power generation turbine exhaust plumes passing close to or over the helideck. In one case an approach had not been particularly well flown. The aircraft had been descending and slowing with its engines at a very low power setting when the collective was raised just as the aircraft flew into hot gas, demanding rapid acceleration from the engines. The sudden change of ambient air temperature, coupled with the acceleration demand, could have caused an engine surge, resulting in loss of power. Whilst the Ninian platforms are normally serviced by Scatsta crews, this flight was performed by an Aberdeen crew who were less familiar with the characteristics of the Ninian.

In another case, when an aircraft was on the helideck of the Anasuria, the HOMP detected a deck temperature which was 10 degrees C above normal ambient temperature. This was again due to turbine exhaust gases being blown along the side of the ship and up across the helideck. In this case, because the turbine exhausts were some distance away, the problem was more one of performance loss rather than turbulence or engine surge. Whilst the Super Puma is not normally performance-limited by high temperatures, other types certainly are. Due to the unpredictable nature of this effect, it is very difficult for crews to plan arrival and departure weights – the effect might arise after the installation weather has been received and performance calculated. Irrespective of performance limitations, increased temperatures will always reduce power margins and this could affect the outcome of an engine failure in the late stages of an approach.

Under certain conditions, flight through turbine exhaust plumes is probably inevitable on particular installations. However the HOMP can help to ensure that appropriate operating restrictions are placed in the Helideck Limitations List (HLL).

6.1.12 Overtorque on landing

HOMP events triggered	
Event No	Title
25B	Maximum take-off torque (2 engines)

The co-pilot was landing at maximum weight on a platform with a restricted sector due to turbulence, when the wind was in this sector but below the windspeed limit for a weight restriction. The existing platform limitations are considered to be satisfactory provided an approach is well flown. However, a combination of the wind being in the turbulent sector and the co-pilot's less than ideal approach resulted in a short duration overtorque, which was not seen by the aircrew. As a result of the HOMP event, the co-pilot raised an ASR.

6.1.13 VNO/VNE exceedance

HOMP events triggered	
Event No	Title
17C	VNO exceedance by 2 knots IAS

A large number of VNO exceedances occurred at aircraft weights over 18,410lbs, where there is a step change in VNO/VNE limits. This showed that crews were failing to remember the change in VNO/VNE limits at high weights. In the past aircrew used to check VNO/VNE before commencing a descent, but this practice ceased.

In one case, an aircraft also exceeded VNE by one knot when descending to an offshore platform (this was too small a margin to trigger the VNE event). The aircraft was heavy and the exceedance was due to a combination of high take-off weight and short sector distance.

6.1.14 Temporary loss of control in flight

HOMP events triggered	
Event No	Title
10A	High normal acceleration above 500 feet AGL

The HOMP detected a high normal acceleration in the cruise (1.7g) when the co-pilot, leaning back to retrieve a water bottle, overbalanced and inadvertently pulled back on the cyclic control at 130 kts, changing the attitude of the aircraft from level to 20 degrees nose up. The captain took the controls, but by the time he had regained control, the aircraft had climbed approximately 1,000 ft (the aircraft was outside controlled airspace at the time). Figure 6.8 shows the plot of longitudinal cyclic pitch (blue), pitch attitude (red), normal acceleration (black) and pressure altitude (green). The HOMP Manager suggested that the crew raised an ASR.

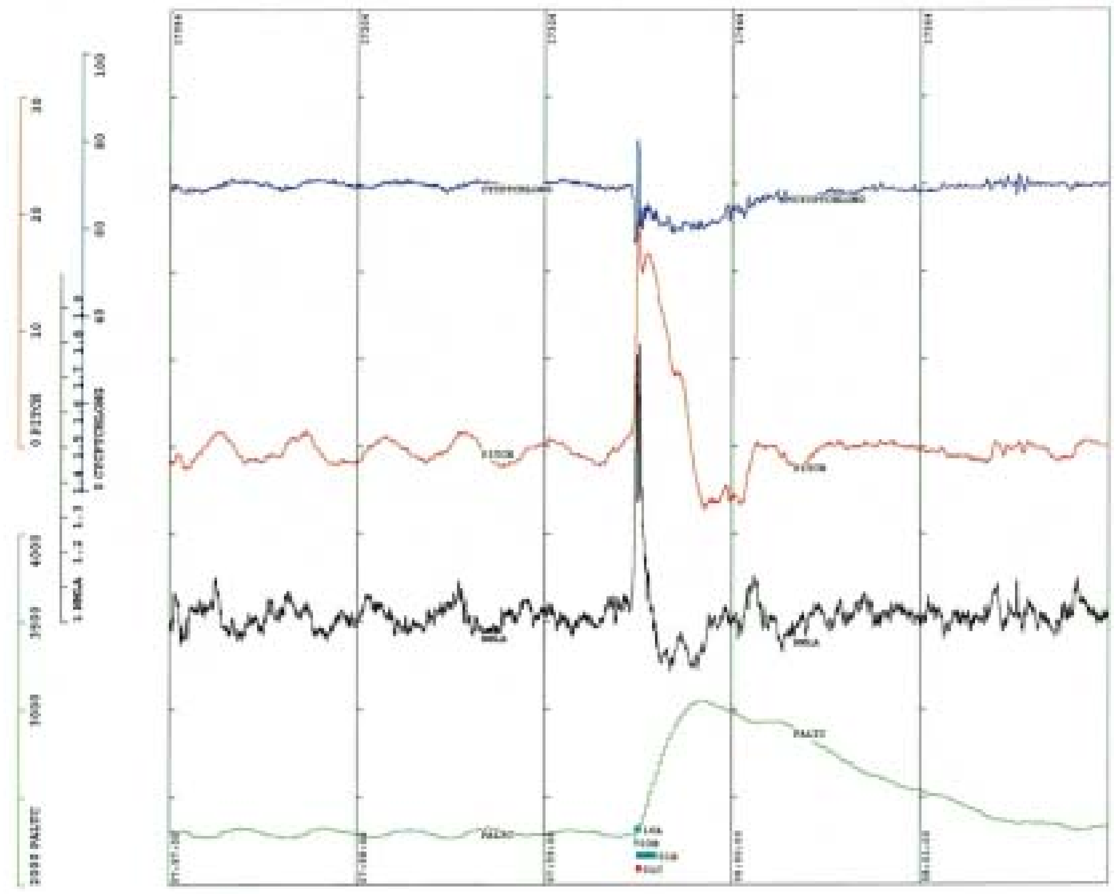


Figure 6.8 Pitch Up During Loss of Control

6.1.15 "Max Ng" check at low height

HOMP events triggered	
Event No	Title
39A	Single-engined flight

An air test was performed for a 'max Ng' check, which involved setting one engine's fuel control lever to idle and demanding full power from the other. The test had been performed at 1,500 feet, however the aircraft subsequently descended to 200 feet AGL and one engine was again set to idle and the other to full power. Performing this test at such a low height created an unnecessary hazard and demonstrated poor airmanship.

On a previous incident involving a Super Puma, during a Max Ng check the drive shaft of the engine at full power disconnected. The aircraft lost considerable height in autorotation until the other engine could be restored to full power, and was only saved from an engine-off landing or crash by the safe height at which the test was being conducted. The HOMP Manager discussed the issue with the Flight Safety Officer, who included it in a routine flight safety newsletter.

6.1.16 Excessive collective pitch in cruise

HOMP events triggered	
Event No	Title
12A	Excessive collective pitch control in level flight

At Scatsta it was necessary to fly procedural IFR approaches at night with a 10 minute separation; if multiple aircraft were returning at the same time an aircraft could be given a delayed approach time. The HOMP detected examples of aircraft flying with greater than the Flight Manual limit for collective pitch and torque in the cruise to achieve a particular arrival time. This may be an example where there is merit in reviewing local ATC procedures. Collective pitch limits were reduced shortly after the aircraft first came into service as a result of the low time before degradation of the gearboxes. Although no relationship could be proved, at the time of the HOMP events it was noted that there had been an increase in the rate of gearbox replacements.

6.1.17 ILS glidepath indication problem

HOMP events triggered
Reported by pilot

During an ILS approach, the co-pilot's glideslope indicator was not functioning correctly and the faulty indicator was being used to fly the approach. This was indicating that the aircraft was on the glidepath, when in fact it was below it and descending. When the functioning indicator was checked the deviation was detected and the aircraft climbed back up to the glidepath. The pilot informed the HOMP Manager of the occurrence.

6.1.18 Engine problem

HOMP events triggered
Reported by pilot

The pilot reported that, during cruise flight, there had been a loss of power on one engine and, at the same time, the Ng had increased. After 30 seconds the engine power reverted to normal. The HOMP data was used to confirm this and a 'split torque' event was created to capture any repeat occurrence. Other problems with the engine were subsequently reported and an inspection revealed that the module two stator vanes had been rotating. The engine was therefore rejected. This example demonstrated the use of HOMP data to troubleshoot an engine problem.

6.1.19 Full-scale fly up at 200 ft during ILS approach

HOMP events triggered
Reported by pilot

A captain visited the HOMP Manager following an ILS approach flown by an inexperienced co-pilot in very bad weather. During the latter stages of the approach, below 500 ft, the captain had been looking out of the cockpit to try to obtain visual references. Approaching decision height, with no outside visibility, he looked back inside and saw nearly full-scale fly-up on the ILS glidepath. A go-around was initiated and the aircraft landed successfully from the second approach. Figure 6.9 shows the instrument view at approximately 250 ft above airfield elevation, with the aircraft in a potentially hazardous position.

Figure 6.9 Nearly Full-Scale Fly-Up at 250 ft

Discussion with the captain revealed ways in which the conduct of the ILS approach could have been changed to make flying the approach easier. ATC had asked the crew to maintain maximum speed, and so most of the approach was flown at 130 kts IAS (110 kts is preferred). Despite that, the approach was well flown until around 800 ft when it was decided to reduce speed to approximately 80 kts.

Many pilots believe that it is easier to land in poor weather if airspeed is low at the bottom of the approach, as there is more time to acquire visual references. Low speed is also preferred because ATC normally expect aircraft to turn off the runway at the first intersection which, in this case, was only about 200 yards past the ILS touchdown markers. However, a late speed reduction de-stabilises the approach and markedly changes the drift angle and required rate of descent to maintain the ILS flight path, making the bottom of the ILS approach very much harder to fly.

During the discussion, the captain realised that improvements could have been made to the way the approach was flown, for example by declining the high-speed request, or slowing down earlier and less, and informing ATC that they would not be able to make the normal turn-off.

Following the reporting of this incident, consideration was given to the creation of a new HOMP event to monitor for any recurrence. However, problems were anticipated with a very high nuisance triggering rate and therefore no event was implemented. Helicopters returning to Aberdeen normally fly a VFR approach, and do not attempt to maintain the ILS approach angle. However the aircraft may well be tuned to the ILS frequency, which would lead to apparent severe glidepath deviations. Even when an aircraft is flying an ILS approach, it would not be possible to determine when the crew establish visual contact with the runway, after which point they would be likely to deviate from the ILS approach path to arrive at the helicopter landing area. It may be possible to devise a complex event algorithm that overcomes these problems, but this was not attempted during the trial.

6.2 Event trends

6.2.1 The importance of trending

In addition to identifying safety issues from individual HOMP events, important information can be obtained from reviewing the rates of event occurrence and detecting any increasing or decreasing trends. For a small operator with only a few people involved in the HOMP, some trends are likely to be relatively obvious but, in order to ensure that a significant trend is not missed, it is necessary to perform a regular review of event trends. In particular, it is important to complete the loop of identifying recurring events, taking corrective action, and then checking for the success of the corrective action as demonstrated by a reduction in the event rate. Monitoring should check that there has been a sufficient reduction in event triggering, and that the rate does not increase again over time as crews forget the issues highlighted or as other factors come into play.

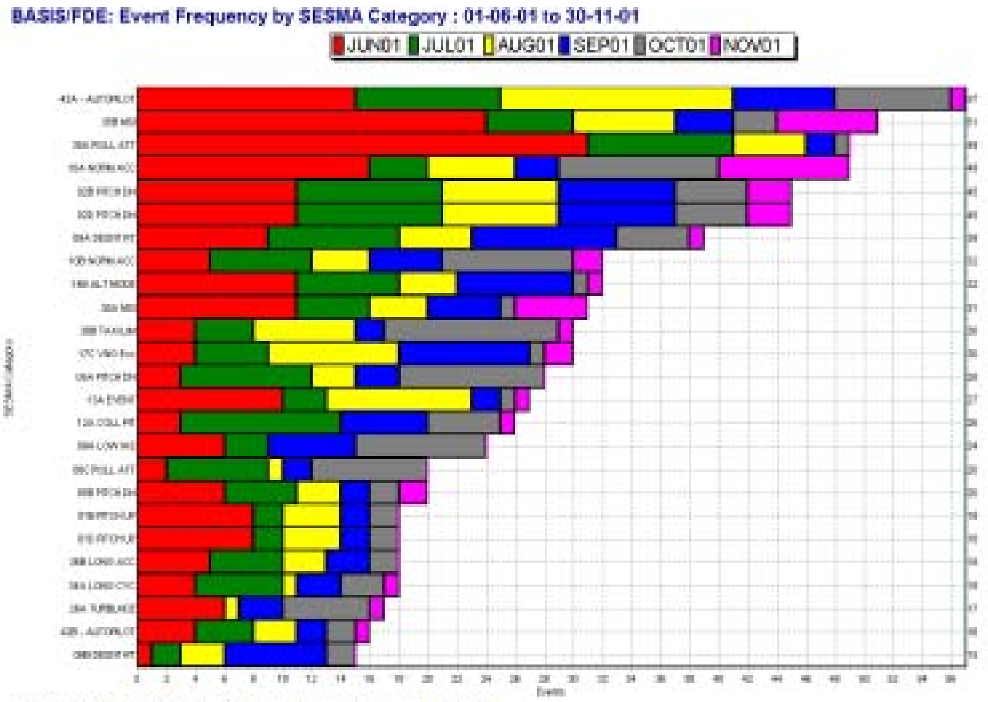
6.2.2 Event rates and trends observed during the HOMP trial

The full FDE module functionality required for HOMP event trend analysis was not available for the first year of the trial, however trends could still be observed qualitatively by the HOMP Manager. One of the early trends detected was the frequent occurrence of take-offs with the cabin heater on (see Section 6.1.9). Having identified this as a recurrent problem, possible actions were considered, and it was decided not to include the item in an already full checklist. When frequently used checklists become too long, they can be counter-productive as the lengthy repetitions increase the likelihood that items are missed, or are enacted without thought. Instead, the issue was included in the first HOMP newsletter, published in late February 2000. Occurrences of this event reduced markedly after the publication but, as it was nearing the end of winter, it was difficult to determine whether this was because of the aircrew response, or whether it was simply due to the warmer weather. However, during the winter of 2000/2001 the occurrence rate remained low. It was therefore concluded that the issue had been adequately addressed, the only remaining requirement was to monitor for any future signs of a reappearance.

Having experienced a rollover accident resulting from inappropriate use of tail rotor pedal and cyclic during taxiing, the flight safety and training departments were naturally very attentive to the issue. Despite this, a number of occurrences were detected of the controls being placed in the rollover zone, and in one or two cases the roll attitude confirmed the proximity to a rollover. Having targeted all the individuals concerned with an explanatory letter and graphs similar to Figure 6.7, and highlighted the issue in an edition of the company flight safety newsletter, there was only a limited reduction in the occurrence rate. This resulted in another campaign, involving a memo from the Chief Training Captain to all trainers reminding them to give the issue high priority, and another newsletter. The occurrence rate then dropped to near zero and remained low, either because all likely offenders had been individually targeted, or because of the general raised awareness. Although the campaign lasted well over a year, a successful outcome was eventually achieved. The experience demonstrated that it is not sufficient to take a single action to attempt rectify a problem – the outcome must be monitored and, if it is not successful, further measures must be taken.

Some events (for example deck motion events) are generated by external factors which are largely beyond pilot control. Attempting to address these events can be more difficult as they can involve other parties. However, it is still important to monitor for such trends because, if a significant adverse trend is noticed, the company has a duty to take whatever measures are required, even if this involves addressing issues with its clients.

Once the FDE module had been commissioned, various event trend charts could be produced, making the task of monitoring event rates and trends much easier. Figure 6.10 shows a histogram of all the events within FDE for a 6 month period (i.e. it includes all nuisance events but no false events), with a filter applied to eliminate training flights or airtests. These flight types include manoeuvres that would not be considered normal for passenger transport flights and so tend to generate large numbers of events. The event algorithms could be modified to only detect events on the appropriate flight type, but it was considered better to detect events on all flights and then filter the data. Indeed, badly conducted training flights could generate unacceptable risks even though no passengers were carried. The data shown in the following figures was produced part way through November 2001, and so does not include all November’s flights.



Filter: Fleet is "SUPER PUMA", Flight Type in range 1 to 2.

Figure 6.10 All Events for Passenger Flights for a 6 Month Period

The large number of events included in this chart is somewhat misleading as the majority of events seen posed a minimal or non-existent flight safety risk. The philosophy was to accept a number of nuisance events because occasionally they pointed to an occurrence not previously thought of. In order to avoid distorting the trend data, the nuisance events were assigned a severity level of zero, whilst all other events were given a positive severity level. The chart presented in Figure 6.11 shows only events assigned a severity greater than zero. In this case training and airtest flights are included because these generated a few significant events.

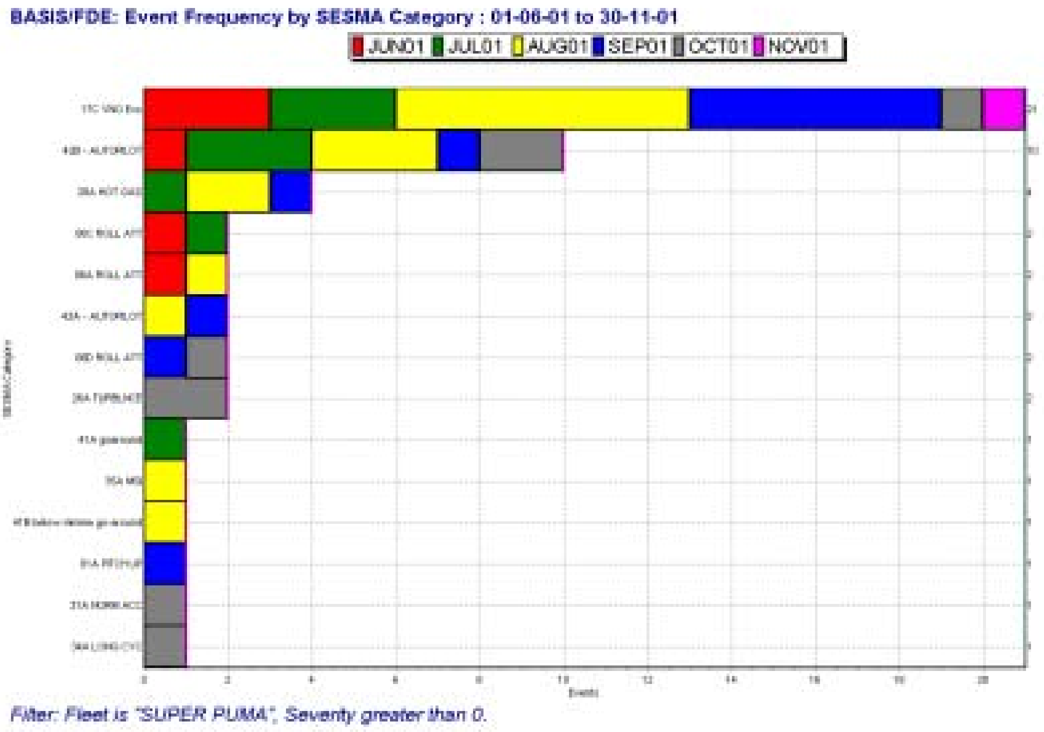


Figure 6.11 Frequency of All Events for All Flights for a 6 Month Period, with Severity >0

This chart does not take into account the fact that an event with an assigned severity of 1 has less significance than one assigned a severity of say 4. Thus rather than plotting events by frequency, it is more meaningful to plot events by cumulative severity as shown in Figure 6.12. This may change the ranking of the events appearing on the chart. In the particular cases shown, the ranking of the top 3 events does not change, although their relative magnitudes do. However, it can be seen that event 35A (Excessive Movement of Deck) moves up from bottom equal to position 4. This was the result of one occurrence being assigned a severity of 5 as it was considered to be quite a serious event (roll angles achieved were +3.7 to –5.5 when the limit was +/-2).

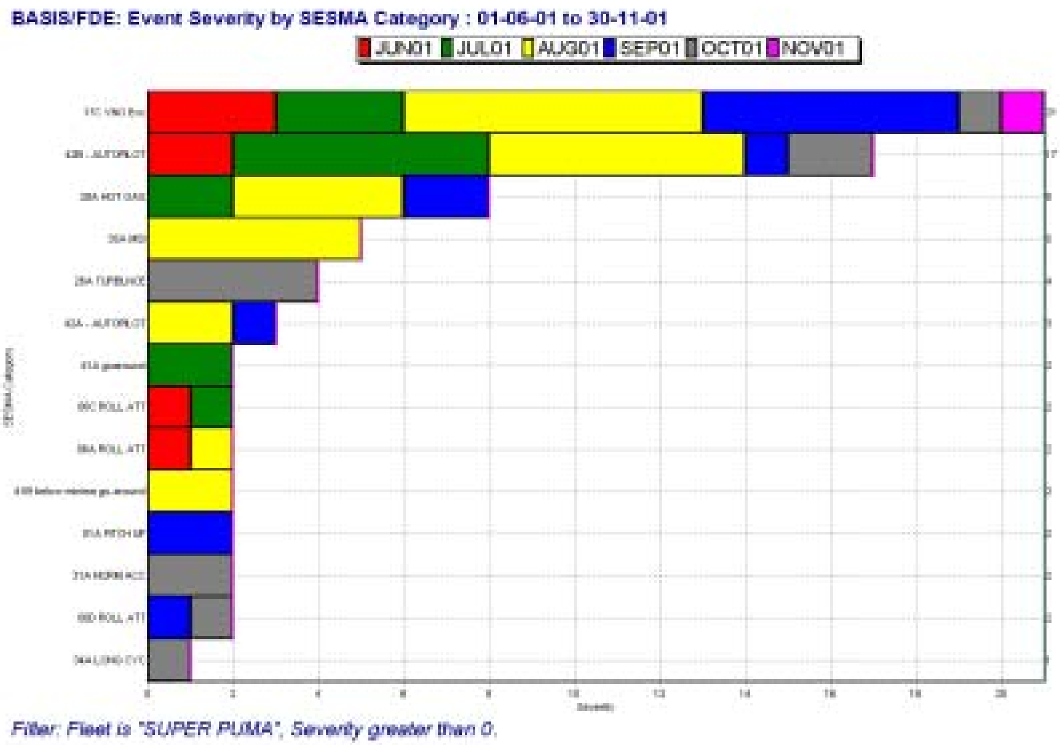


Figure 6.12 Cumulative Severity for All Events for a 6 Month Period

An earlier production of Figure 6.12 was used to determine the contents of the September 2001 HOMP newsletter to aircrew. Some of the events (e.g. 28A - Flight Though Hot Gas, 35A - Excessive Movement of Deck, 26A - Pilot Workload/ Turbulence) related to issues largely outside pilot control. It was therefore decided to address the pilot-controlled issues relating to events 06A–D (Roll Attitude), 17C (VNO Exceedance), 41A/B (Go-Around) and 42A/B (Autopilot Engaged On Ground). Whilst many 41 A/B and 42 A/B events were generated by legitimate operational circumstances (i.e. were nuisance events), the newsletter was intended to address those cases where they were inappropriate.

Having published the newsletter, the subsequent trend of these specific events was monitored using the chart shown in Figure 6.13. This gives the variation in cumulative event severities between the last 3 months and the previous 3 months, with green indicating a reduction and red an increase. Even taking into account the slight reduction in the total data for the last 3 month period, it can be seen that the cumulative severity of the targeted events reduced markedly, showing the newsletter to have been very effective. Event 6D was the only exception to this positive result. The two new cases were both the result of training flights exceeding the Flight Manual limit for bank angle at high weights whilst carrying out “instrument recovery from unusual attitude” exercises. The two different training captains involved in the events were reminded of the Flight Manual limit. It would be necessary to continue to monitor these trends to detect any signs of a future relapse.

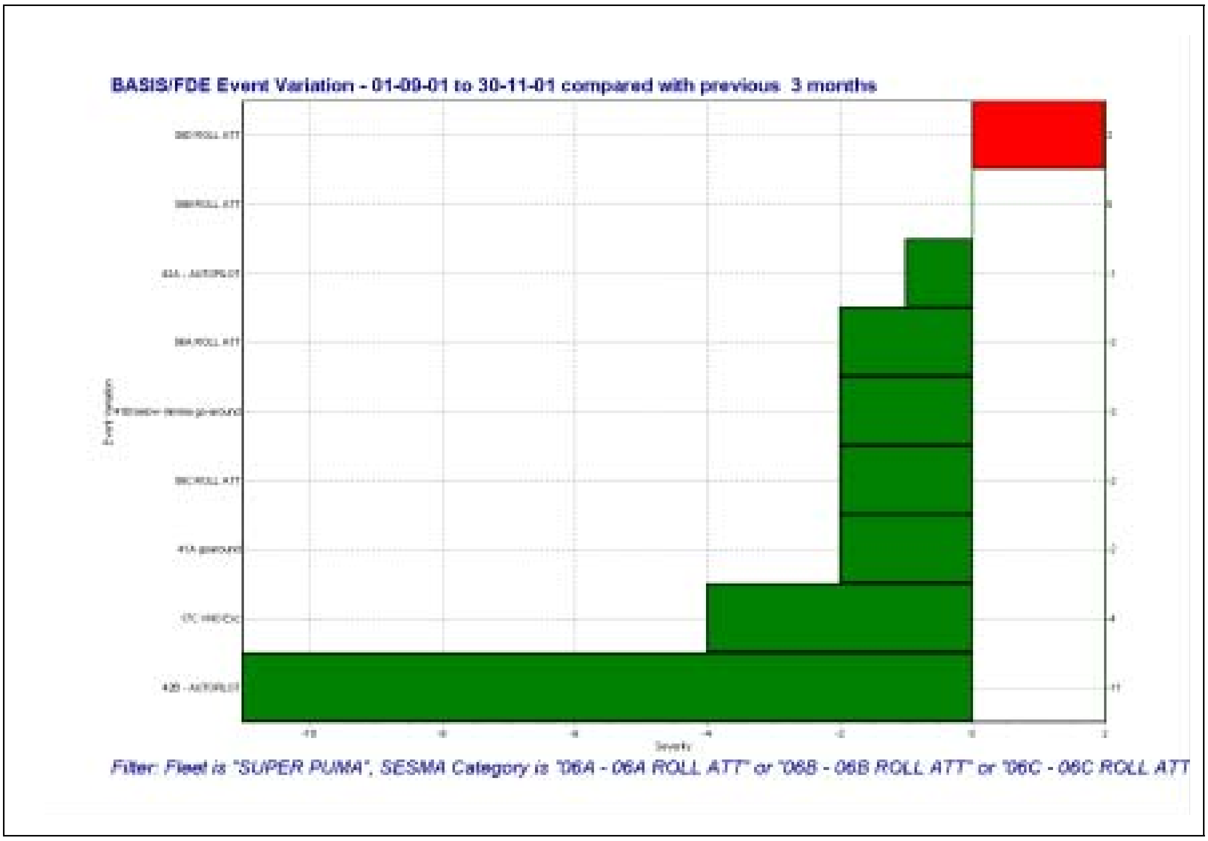


Figure 6.13 Variation of Severity of Events Covered by September 2001 Newsletter

Event frequencies are of course affected by the amount of flying carried out and so it may be appropriate to factor the figures. Factoring could be carried out either by flight hours or by flight sectors, but as the majority of events are triggered during take-off and landing, it is more appropriate to factor by sectors. FDE permits the importing of flight sector information, including the departure and arrival locations. This not only allows factoring by total flight sectors, but also permits more accurate trends to be observed for individual locations.

For example, Figure 6.14 shows instances of event 28A (Flight Through Hot Gas), plotted by location. This event relates to the aircraft encountering sudden changes in air temperature, normally due to the proximity of turbine exhausts on offshore installations. From this chart it can be seen that the Ninian Central is ranked top, whilst the Anasuria is some way down. However, after factoring by the number of landings on each installation, the picture is somewhat different as Figure 6.15 shows. The Anasuria, with fewer landings, now moves up to second place behind the Ninian Central, which is consistent with the perceived problems at the two installations.

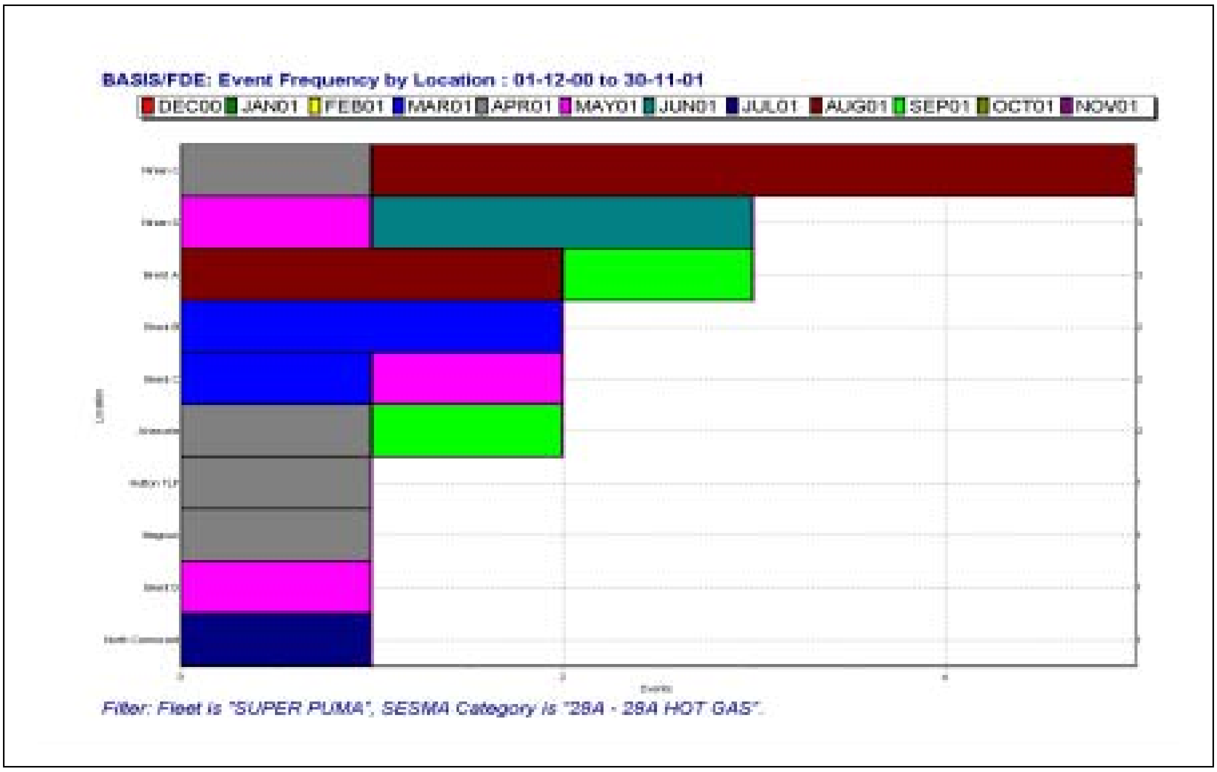


Figure 6.14 Event 28A "Hot Gas" by Location

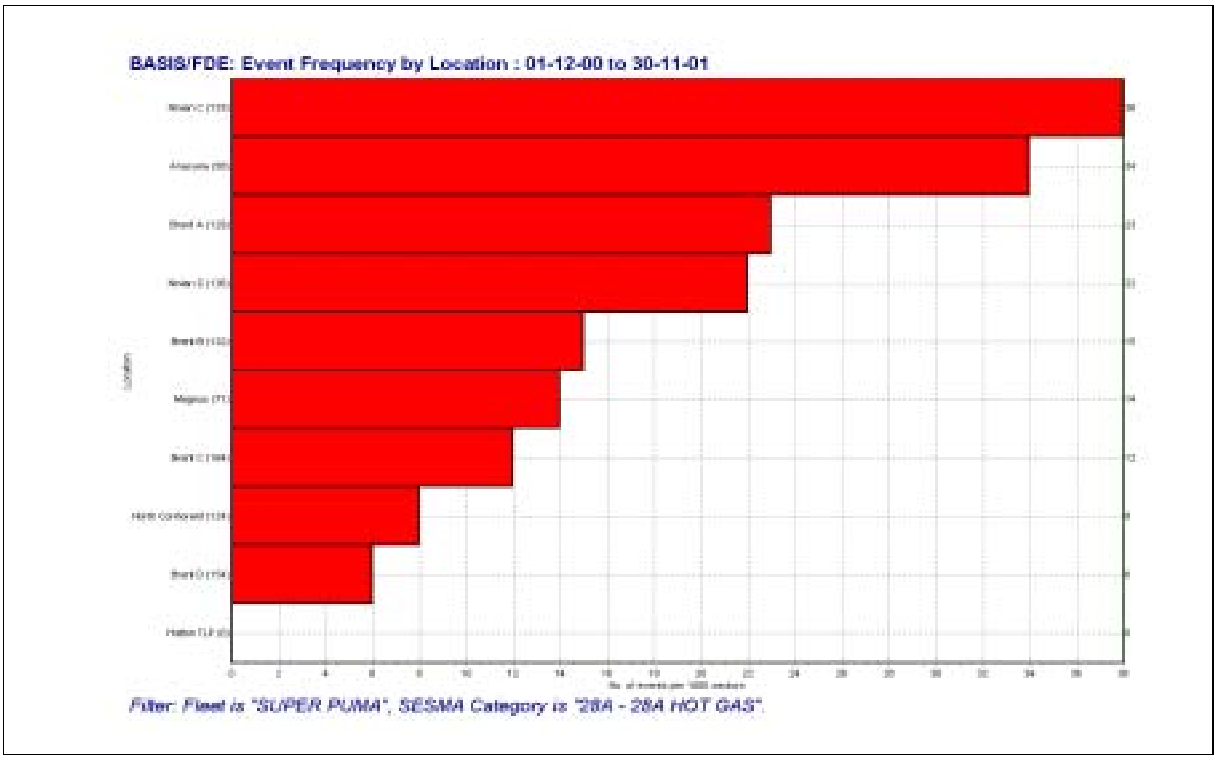


Figure 6.15 Event 28A "Hot Gas" by Location, Factored by Number of Landings

Many other types of trend charts can be produced. For example, Figure 6.16 shows the occurrence rate of event 17C, grouped by operating base. A clear difference can be seen between the top row and the bottom row, representing the two bases involved in the HOMP trial. The main reason for this marked difference was that many of the sectors flown from the top base were relatively short. Therefore the aircraft were often above the weight at which there was a step change in VNO when at the top of the descent, giving them a much reduced VNO. There was some difference between the number of flights analysed from the two bases, but not nearly enough to account for the different event rates.

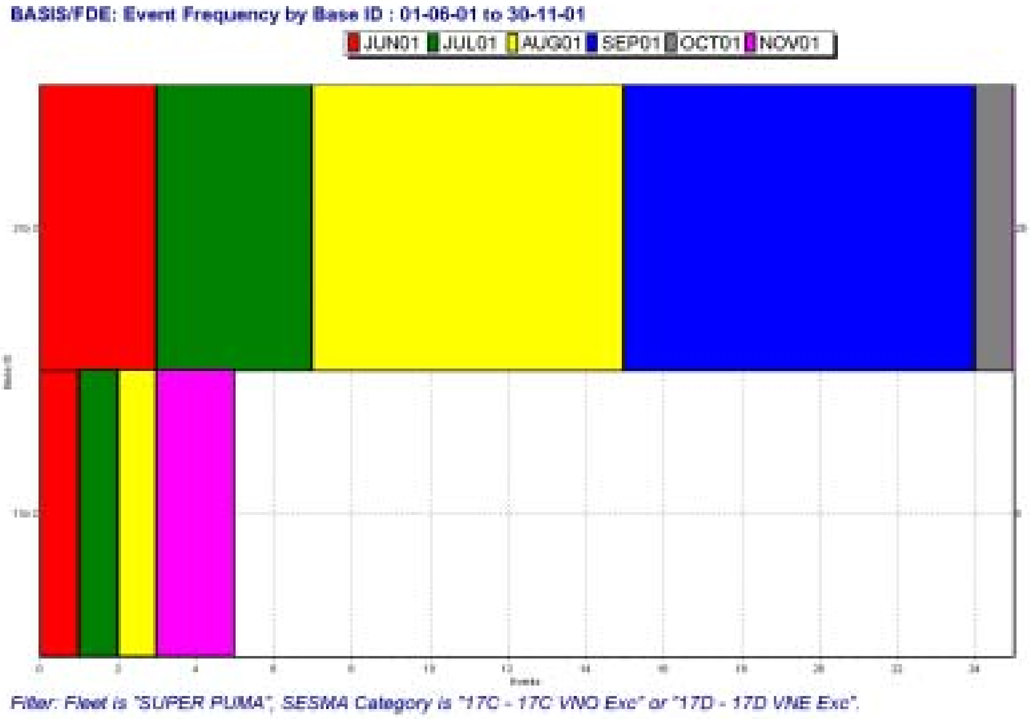


Figure 6.16 Event 17C by Operating Base

By use of the encrypted and confidential pilot identities, which only the HOMP Manager could decode, the sensitive issue of grouping of events by individual pilot could be examined, as shown in Figure 6.17. The highest ranking individual had 6 occurrences of a particular event over the period, whilst many other pilots had none. This suggested that there was an issue with the particular individual. In fact the event did not represent a great hazard as it related to taxiing technique but, if repeated over a long period, it could possibly result in damage to the aircraft. The individual concerned was a very experienced pilot but relatively new to this type, and the technique he was using was appropriate to his old type but not to the Super Puma. The trend was only identified whilst preparing material for this report, which shows that some trends are not easy to identify without automatic trend detection.

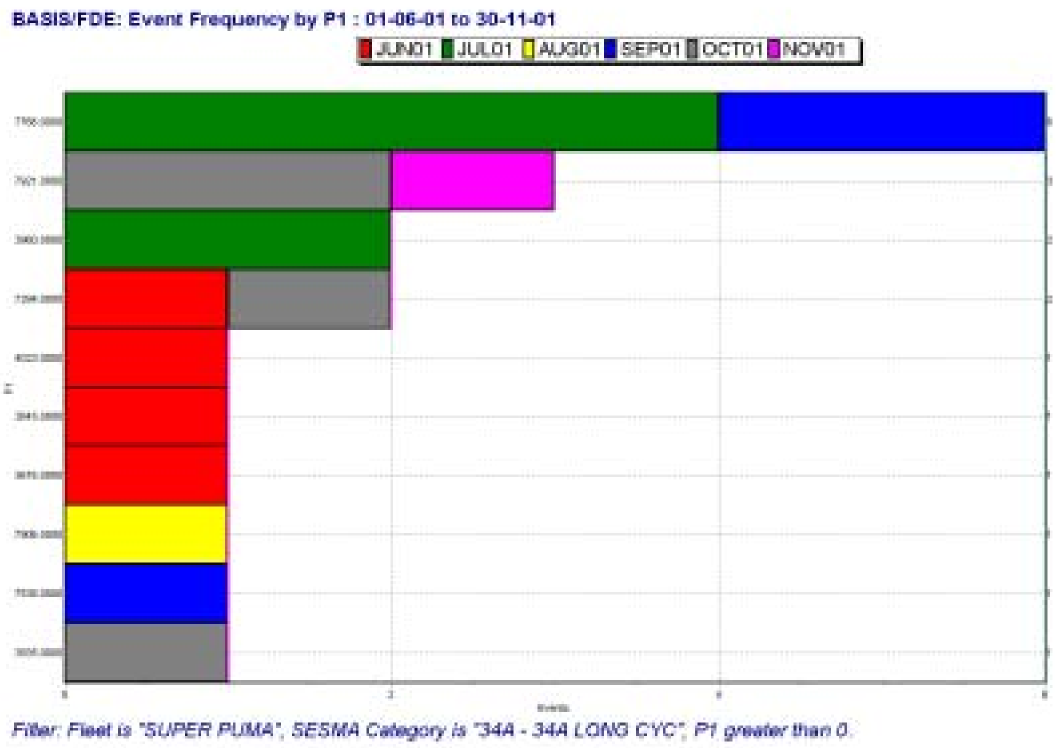


Figure 6.17 Event 34A by Pilot 1 Identity

6.3 Discussion

The safety benefits of the HOMP event analysis were identified at an early stage of the trial when the first events were generated and corrective or preventative measures were taken. The trial identified safety issues which the operator was able to resolve and demonstrated that the HOMP is a highly effective tool for enhancing operational safety.

As well as detecting crew-induced incidents, the HOMP events provided evidence to support crews concerns about external factors such as severe weather or incorrectly reported installation data. The HOMP detected a wide variety of events and the follow-up of these identified a range of operational issues relating to:

- Pilot knowledge and skill
- Gaps in the training system
- Cockpit resource management
- Operating procedures
- Environmental operating limitations

A number of the most notable individual events detected by the HOMP could be related to previous North Sea helicopter incidents and accidents, or accidents elsewhere on similar helicopter types. Table 6.1 references five of the events described in Section 6.1 and identifies previous incidents and accidents which have some relevance to these.

Table 6.1 Accidents Related to HOMP Events

Event reference	Related accident, and reference	Brief accident details
6.1.1	Canadian helicopter accident Transportation Safety Board of Canada report circa 1988	The AS332L rolled over when the crew lifted off with full left tail rotor pedal applied during a training flight.
6.1.3	G-BKJD near Petrojarl on 6 December 1994 AAIB Synopsis 5/95	During a go-around, the 214ST lost forward airspeed and entered a dive, recovering at very low altitude.
6.1.4	G-BOND DSV Mayo in North Sea, April 1992 AAIB Report 11/92	Wave hit stern of vessel during rotors running turn-around causing aircraft to move backwards on deck, resulting in HLO being struck by main rotor.
6.1.10	G-TIGT Aberdeen Airport AAIB Bulletin 6/96	After off-loading passengers, the AS332L rolled over during a turn whilst taxiing to the shutdown point.
6.1.15	G-PUMB Aberdeen Airport AAIB Bulletin 11/99	As a result of a maintenance error, the AS332 lost drive from one engine during a “max Ng check”.

There are a number of unique difficulties associated with helicopter offshore operations which can make them more hazardous than other types of helicopter transport operation. These include:

- Structure-induced turbulence and downdrafts
- Hot exhaust gas plumes from power generation turbines
- Hot gas, flame and smoke from flare stacks
- Unburned hydrocarbon gas discharge from unlit flare stacks or rapid blow-down systems
- Obstacles on the final approach or take-off/go-around path
- Poor quality meteorological and installation data reports from inexperienced observers
- The pitching, rolling and heaving motion of ships and floating platforms during approach and landing and whilst on deck
- Non-precision instrument approaches to an installation in bad weather using only on-board equipment such as weather radar
- Lack of flight-manual procedures for take-off and landing at elevated offshore heliports
- Salt/seawater ingestion

The HOMP trial detected events relating to many of the difficulties listed above. Without HOMP event information, an operator has no independent information on operational risks which could lead to future incidents or accidents. A HOMP provides the opportunity to identify these risks and take action before they have any serious consequences. The ability to monitor risks to identify any requirements for operational changes, and then monitor the effectiveness of these changes, is a key asset of the HOMP.

Corrective or preventative measures which were taken as a result of the HOMP event analysis included:

a) Confidential discussion of individual events with flight crew to debrief the crew on all the relevant factors relating to the event, identify the lessons learned, and to remind crew of correct SOPs.

b) The issuing of newsletters highlighting individual (de-identified) events or event trends and, again, reminding crew of correct SOPs.

c) Prompting the raising of Air Safety Reports. The operator's existing safety management processes then ensure that necessary actions are taken to improve operational practices and procedures.

d) Contact with training and safety staff to discuss events and trends, resulting in training issues being addressed and, in some cases, action being taken to modify procedures.

Whilst significant events were followed up with flight crew on an individual basis, event trend analysis was shown to be a valuable tool for identifying undesirable trends which could best be addressed by the issuing of newsletters to all crew, and also by feedback into the training process. When such action was taken, the trend analysis was also able to show the effectiveness of that action, enabling the HOMP Manager to determine whether further action was required. Analysing trends for different bases highlighted differences in the rate of occurrence of particular events between the main operating base and a satellite base. This is a valuable tool ensuring that consistent standards are maintained across all operating bases.

The analysis of event trends by location confirmed prior experience regarding issues with particular installations. For example, the analysis highlighted the Ninian Central and Anasuria as the installations with the most frequent hot exhaust gas problems. The analysis also uncovered previously undetected trends, for example identifying that a single pilot was responsible for producing a large percentage of the events in one particular category.

Including all the events generated by the system in a trend display did not result in a very meaningful output. However, when 'nuisance' events (given a severity value of 0) were filtered out, the resulting trend charts contained useful information. The most relevant output was generated when severity levels were allocated to events and trends of 'cumulative event severity' were produced.

The event severity scale implemented in the second year of the trial proved to be a very useful addition to the HOMP system and experience did not indicate any need to amend the descriptive categories. However, when the category scale numbers were used to generate cumulative severity, the result was not truly representative. For example, 10 occurrences of a category 1 event (which includes in its definition "no actual safety risk") clearly did not, and would not be expected to, equate to one event of category 10 ("accident occurred"). Referring to Section 2.1.1, however, it is also true that the larger the number of lower category events the greater the risk of a higher category event. The relationship is clearly more complex than the simple linear scale employed and more development is required. Since it is desirable to work with a simple scale when assigning severity values during event analysis, the solution may be to use a non-linear scale, or for FDE to include a lookup table of weightings, allowing it to calculate more appropriate cumulative severities. This approach has the advantage that if the weighting values need to be changed, the results will be reflected in all the data stored in the FDE system, rather than just new entries.

The FDE module offered a large number of trend chart options. The HOMP Manager had to decide which charts to produce and, with such a number of possibilities, it was possible that a significant trend could be missed. There would be benefit in developing techniques to automatically search for, and then highlight, hidden trends in event data.

In addition to generating safety benefits, the HOMP event analysis also provided some useful information to engineering personnel. By detecting excessive use of collective pitch which could impact gearbox reliability, and monitoring for a re-occurrence of an engine problem, the HOMP trial demonstrated an ability to provide engineering benefits. The HOMP was also able to detect incorrect FDR parameter data as a result of aircraft sensor or wiring problems, and should simplify FDR serviceability checks. All the aircraft involved in the HOMP trial were equipped with integrated HUM and FDR systems, with the HUMS performing exceedance monitoring of maintenance manual limits. Additional engineering benefits would be obtained from a HOMP implementation on any aircraft equipped with FDRs only.

Section 7 HOMP Trial Results - Flight Data Measurements

Intended to complement the events, the flight data measurements generated during the HOMP trial proved to be of significant value. Section 7 presents example results to illustrate the various types of information which could be derived from the flight data measurements, and the ways in which this information can be used. The database of measurements used in all the analyses described below was generated by reprocessing one year of flight data from the HOMP trial aircraft, and contained over 7,900 flight sectors.

7.1 Flight information

The flight information contained in the HOMP measurement database consisted of key information about each sector flown. This included departure and arrival locations, location type, take-off and landing weights, sector times, numbers of passengers etc. This information was extracted directly from BHL's Operational database, and its primary use in the HOMP was to enable the filtering or grouping of other measurements in the database. For example, grouping measurements by departure or arrival location enabled the comparison of measurement values for different airfields or offshore platforms.

7.2 General flight data measurements

The general flight data measurements are listed in Tables 4.4 and 4.5 in Section 4.4. One of their main uses in the HOMP trial was to determine appropriate trigger limits for events. For example, a review of the HOMP events showed that events 21A (High Groundspeed Within 20 seconds of Rig Landing), and 21B (High Groundspeed Within 10 Seconds of Airport Landing) were not being triggered. Charts were produced to determine actual groundspeed values at 20 seconds from a rig landing and 10 seconds from an airport landing. The groundspeed trigger levels for both events were originally set to 60 kts but, following a review of the measurement data, they were reduced to 35 kts. By way of an example, Figure 7.1 shows groundspeed values 20 seconds from a rig landing; the vertical axis is the number of measurements and the horizontal axis is the groundspeed.

Similarly, where excessive numbers of events were being triggered, the measurement data was used to determine appropriate increases in trigger levels. The measurement data proved to be very useful for this purpose and, without it, optimizing event trigger levels would have involved a lengthy and time consuming trial and error process.

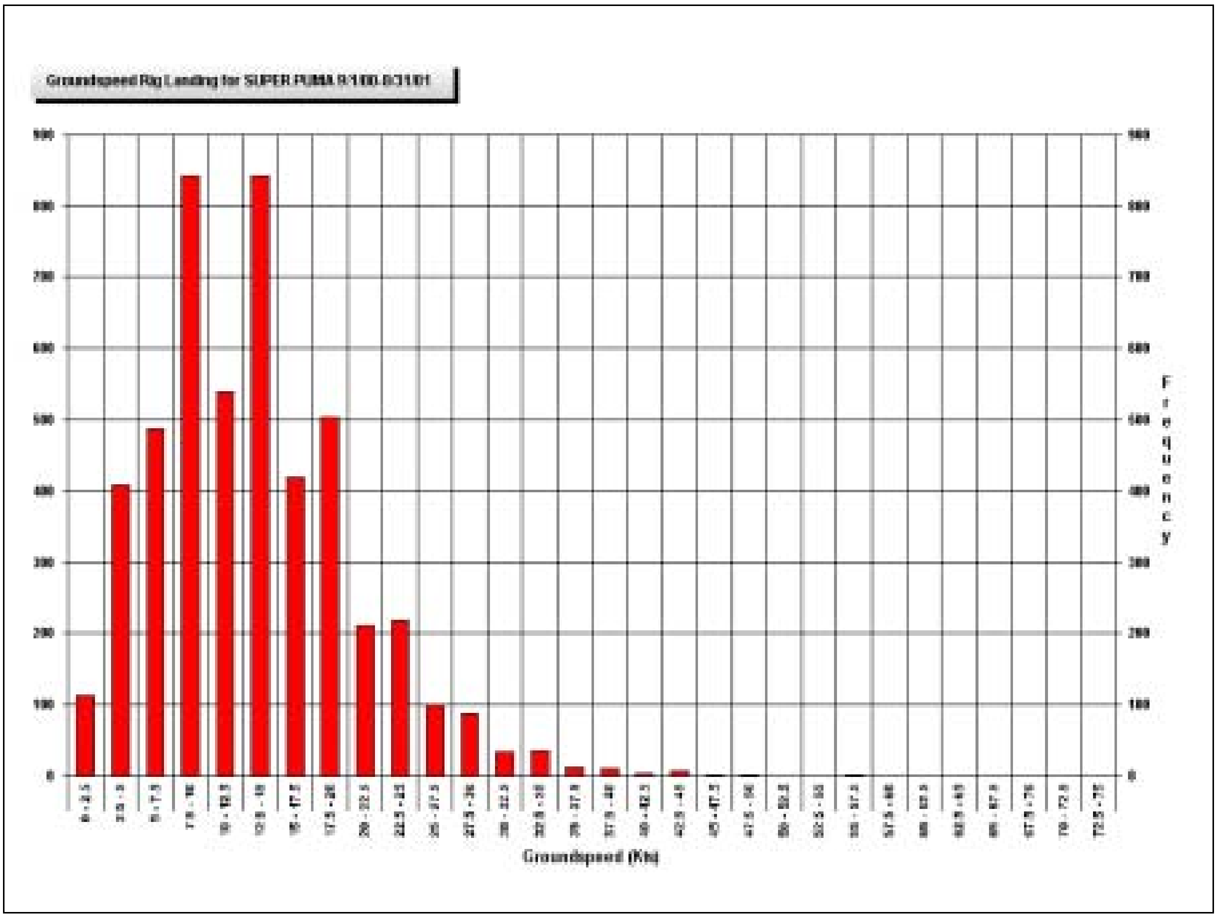


Figure 7.1 Groundspeed 20 Seconds from Rig Landing

The general measurements could also be used in an investigative process to obtain background information when investigating a particular event, or to prove or disprove a theory about a possible operational problem. For example, if an event which had been triggered suggested a problem with a particular installation, the measurement database could be used to obtain much more information on that installation, and thereby help to determine whether a problem actually existed.

There were many other types of analysis which could be performed with the general measurements. To illustrate this, Figure 7.2 shows a plot of average fuel consumption vs. sector length. It was also possible to calculate an average fuel consumption for each airframe.

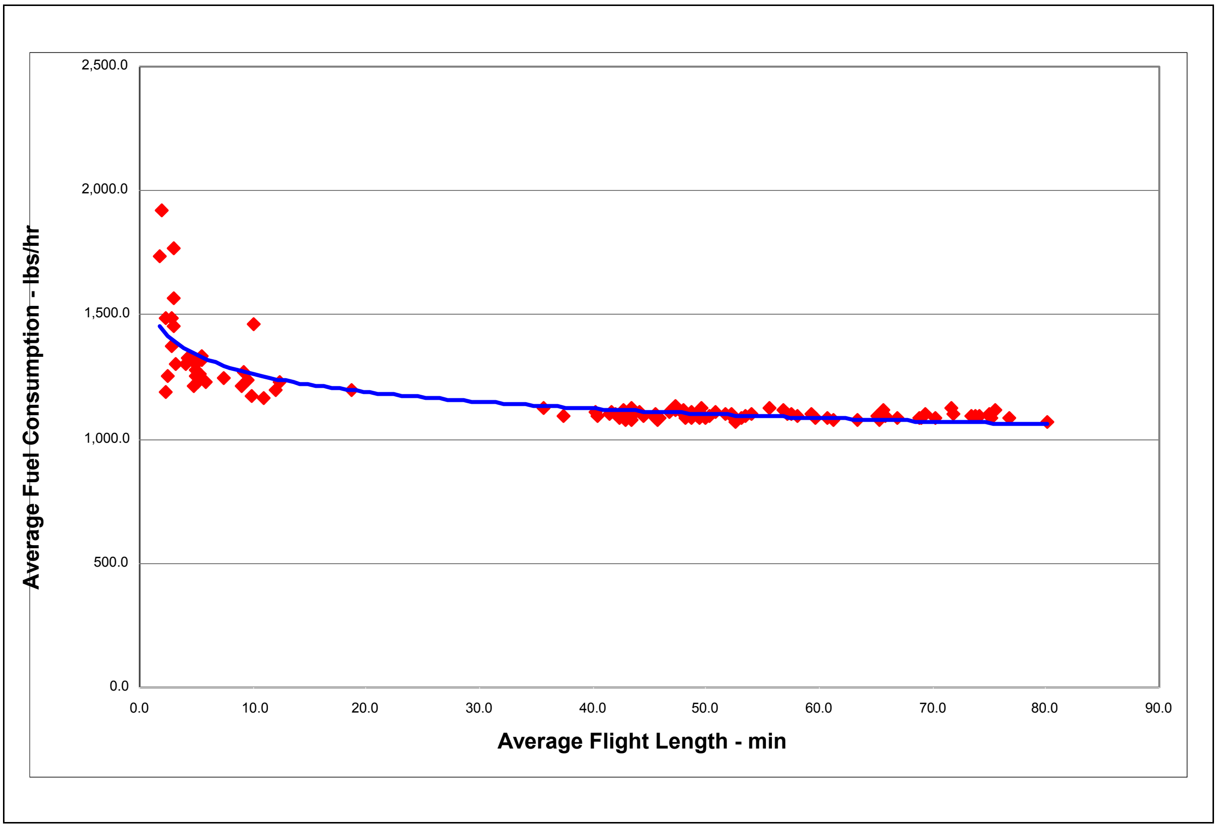


Figure 7.2 Average Fuel Consumption vs Sector Length

7.3 Mapping the helideck environment

7.3.1 Structure induced turbulence

A derived parameter was developed by BHL to provide a measure of turbulence on an offshore approach based on rapid movements of the collective lever (the background to this was described in Section 5.4.1.4). A histogram of the turbulence measurements for offshore landings is shown in Figure 7.3; the vertical axis is the number of measurements and the horizontal axis is the value of the turbulence parameter. Where pilot initiated turbulence reports were raised they were always associated with high turbulence measurement values, demonstrating good correlation between the HOMP measurement data and the actual operating environment.

Turbulence on take-off and landing offshore can result in a very high pilot workload, with loss of control or over-torqueing an ultimate possibility. Whilst crews will normally file a turbulence report following unexpected encounters with such conditions, these can occasionally be omitted and certainly crews are unlikely to file a report describing turbulence which was as expected, or a report indicating that there was no turbulence when the HLL indicated otherwise. Having a measurement and an associated event to detect turbulent conditions encouraged the filing of reports, and conditions at the time could be checked against the HLL to determine whether the level of turbulence experienced was to be expected. If the turbulence was higher than expected, or if an aircraft limitation was exceeded whilst operating within the HLL limits, there is clearly a need to look closely at the corresponding HLL entry and consider an amendment.

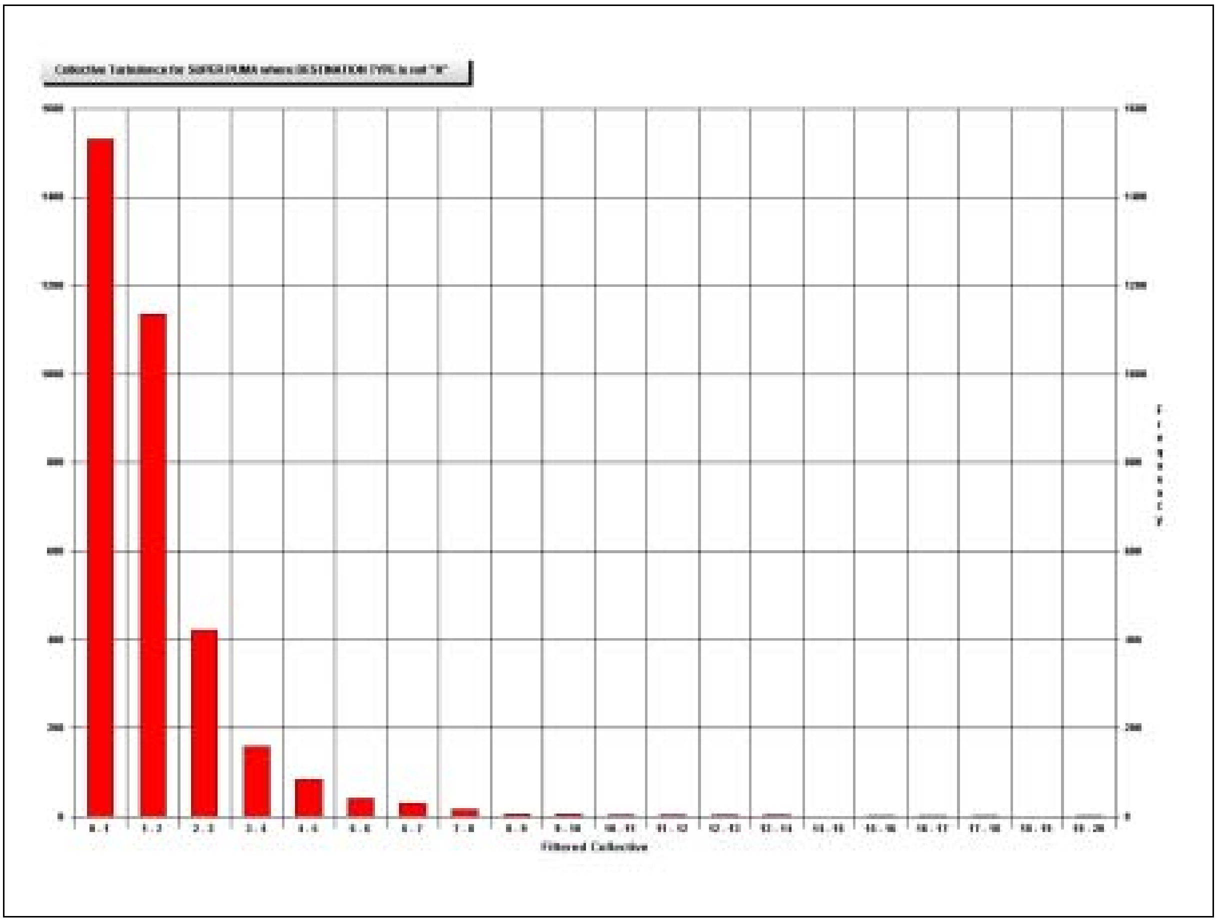


Figure 7.3 Turbulence Indicator

Experience shows that the vast majority of offshore approaches are non-turbulent and only a few are significantly turbulent. Therefore the histogram presented in Figure 7.3 provides a means to empirically calibrate the measurement into, perhaps, 3 levels; low, medium and high turbulence. Values were chosen as follows:

Low:	0 to 6
Medium:	6 to 9
High:	Greater than 9

It is recognised that this calibration is subjective. Efforts are being made to scientifically calibrate the measurement as part of separate research (described in Section 5.4.1.4) aimed at developing a pilot workload-based turbulence criterion for helideck design.

Having developed the turbulence measurement, it could be used to map the helideck environment by correlating it with GPS-derived flight data measurements of wind speed and direction. HOMP measurements gathered on routine operations could be plotted to produce a chart for any platform showing levels of turbulence related to wind speed and direction. On the assumption that the final approach track was flown substantially into wind, the resulting charts could then be used to verify the information in the HLL and to help to indicate when and where revision of the HLL should be considered.

Figure 7.4 presents a chart of the HOMP-generated turbulence data for the Brae A platform, which has significant operating restrictions in certain wind directions. Each plotted point corresponds to a landing and is plotted at a position to reflect the measured wind direction (magnetic heading) and strength. Its colour represents the amplitude of the measured turbulence parameter, split into groups of low, medium or high values.

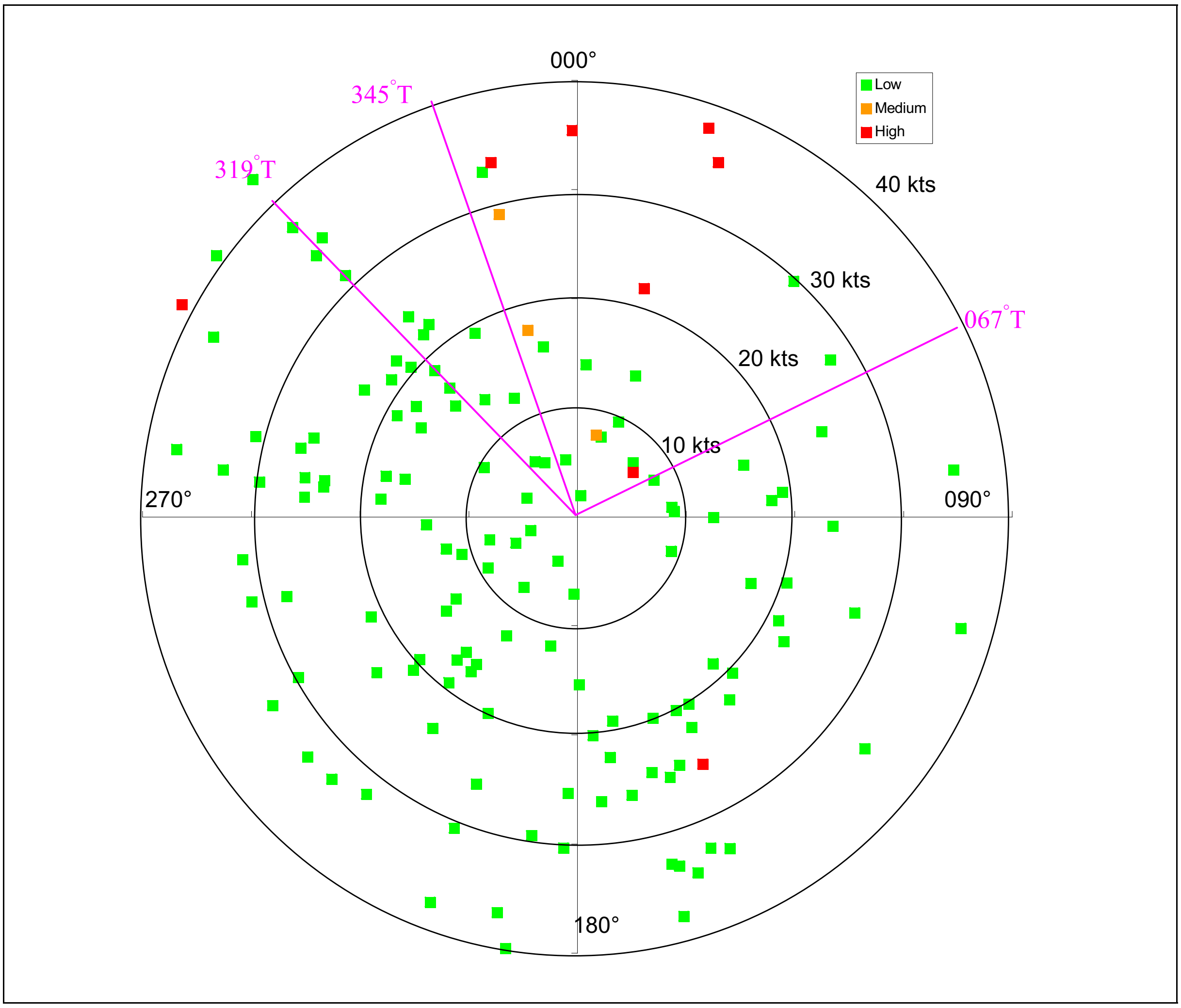
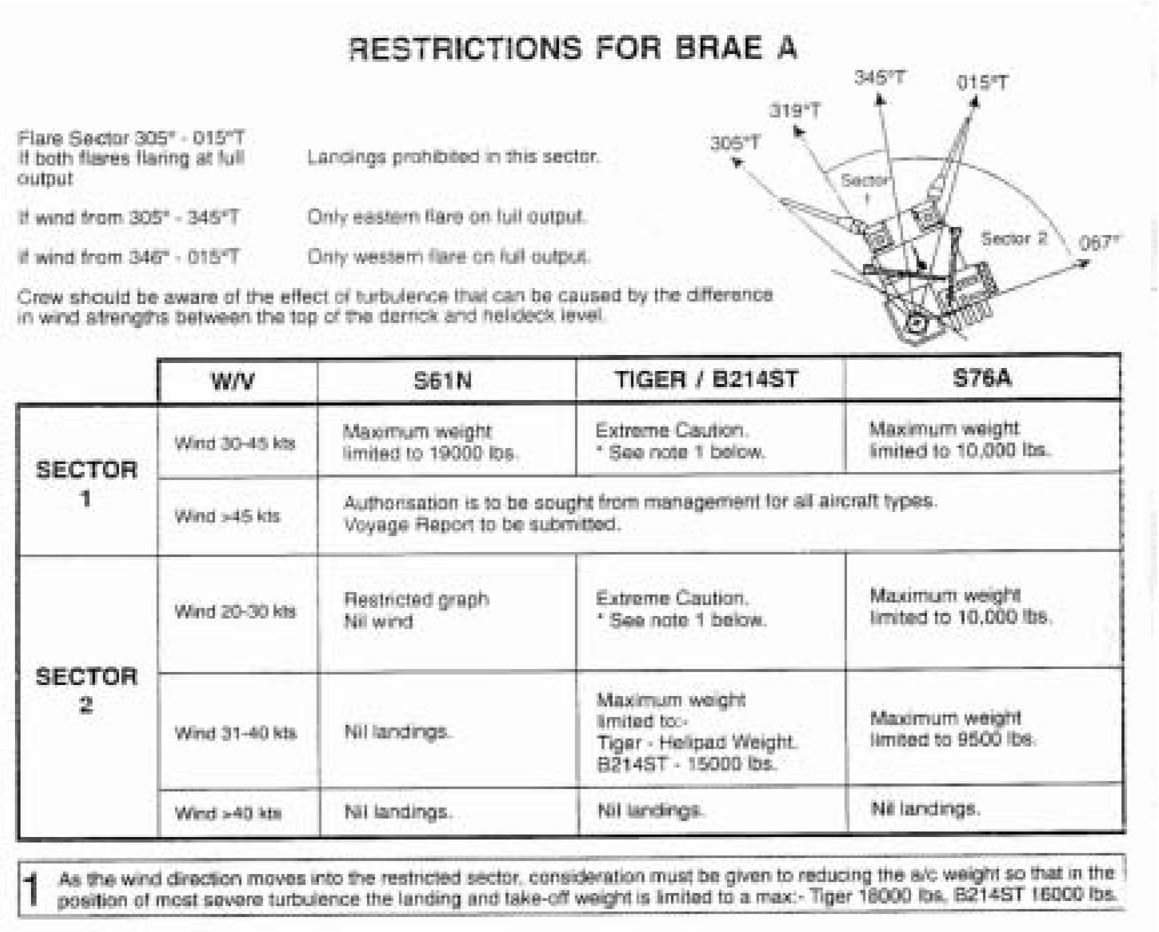


Figure 7.4 Wind Vector and Turbulence Parameter for Brae A Platform

Figure 7.5 shows the restrictions for Brae A as published in the HLL. The restricted sectors (true headings) have been superimposed on the turbulence data in Figure 7.4, with a correction applied to account for the difference between true and magnetic North. High values of the turbulence indicator correlate well with known turbulent sectors for the platform, showing how the data can be used for 'mapping' the helideck environment. The process is not entirely accurate, for example the measured wind direction relies on the aircraft being flown in balance during the measuring period, and the turbulence parameter is influenced by any tendency for the pilot to over-control. One probable and one possible rogue point can be seen on the chart. A planned improvement in the control of the wind measurements should improve the data by eliminating any occasional inaccurate wind direction measurements. With the large amount of data that will accumulate over time, especially once all the aircraft are gathering data, a representative picture of the environment should be obtained.



RESTRICTIONS FOR BRAE A

Flare Sector 305° - 015°T If both flares flaring at full output	Landings prohibited in this sector.
If wind from 305° - 345°T	Only eastern flare on full output.
If wind from 346° - 015°T	Only western flare on full output.

Crew should be aware of the effect of turbulence that can be caused by the difference in wind strengths between the top of the derrick and helideck level.

	W/V	S61N	TIGER / B214ST	S76A
SECTOR 1	Wind 30-45 kts	Maximum weight limited to 19000 lbs.	Extreme Caution. * See note 1 below.	Maximum weight limited to 10,000 lbs.
	Wind >45 kts	Authorisation is to be sought from management for all aircraft types. Voyage Report to be submitted.		
SECTOR 2	Wind 20-30 kts	Restricted graph Nil wind	Extreme Caution. * See note 1 below.	Maximum weight limited to 10,000 lbs.
	Wind 31-40 kts	Nil landings.	Maximum weight limited to:- Tiger - Helipad Weight. B214ST - 15000 lbs.	Maximum weight limited to 9500 lbs.
	Wind >40 kts	Nil landings.	Nil landings.	Nil landings.

1 As the wind direction moves into the restricted sector, consideration must be given to reducing the a/c weight so that in the position of most severe turbulence the landing and take-off weight is limited to a max:- Tiger 18000 lbs, B214ST 16000 lbs.

Figure 7.5 HLL Limitations for Brae A

A similar chart (Figure 7.6) was also produced for the Brae B. However, when comparing the HOMP-generated turbulent points with the HLL limitations for this platform (shown in Figure 7.7, with the restricted sector being superimposed on Figure 7.6), the points did not appear to be in the right place. The turbulence was being encountered with a northerly wind, whereas the HLL restricted sector was 030° - 070° and due to the generator turbine exhausts.

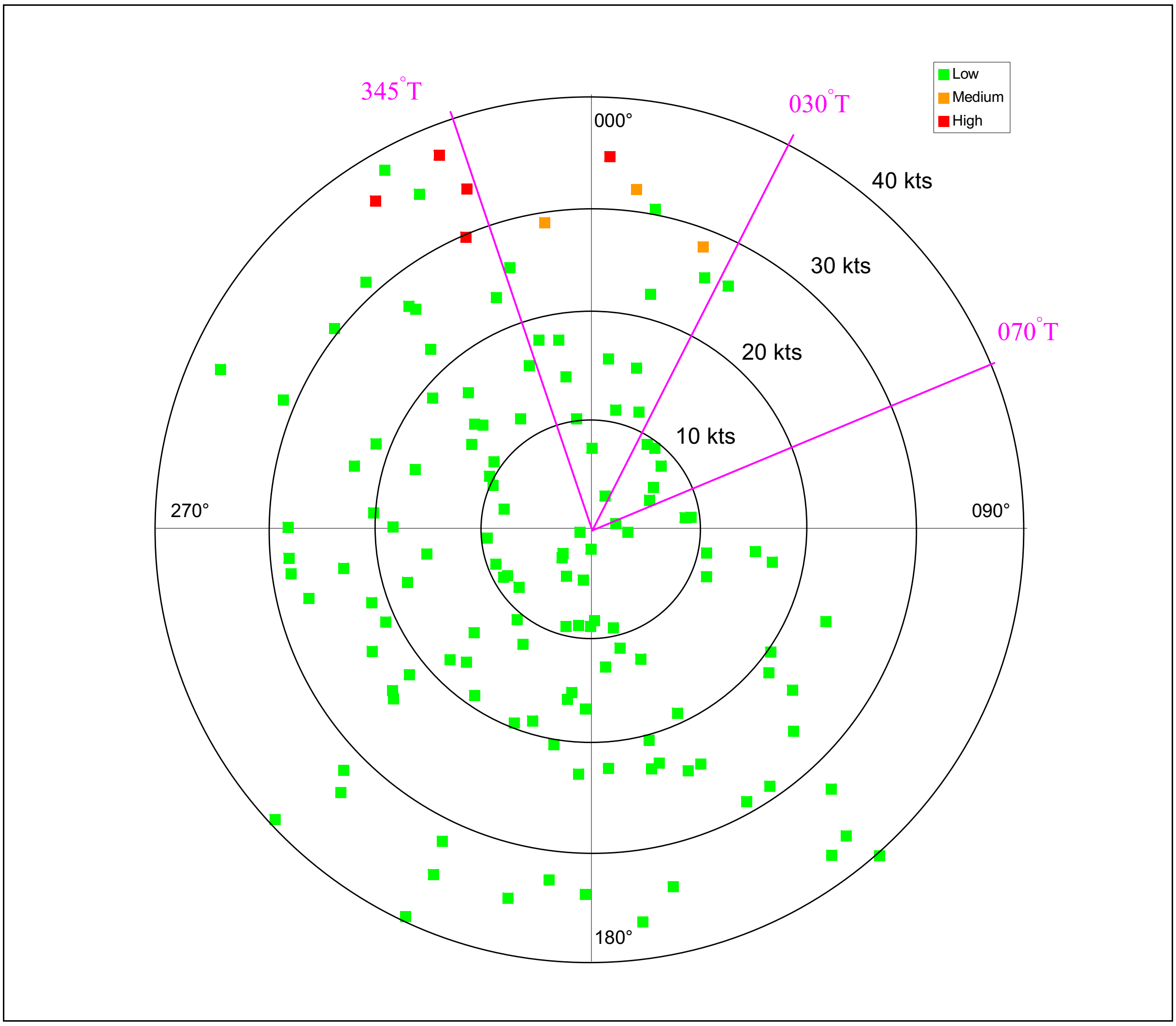
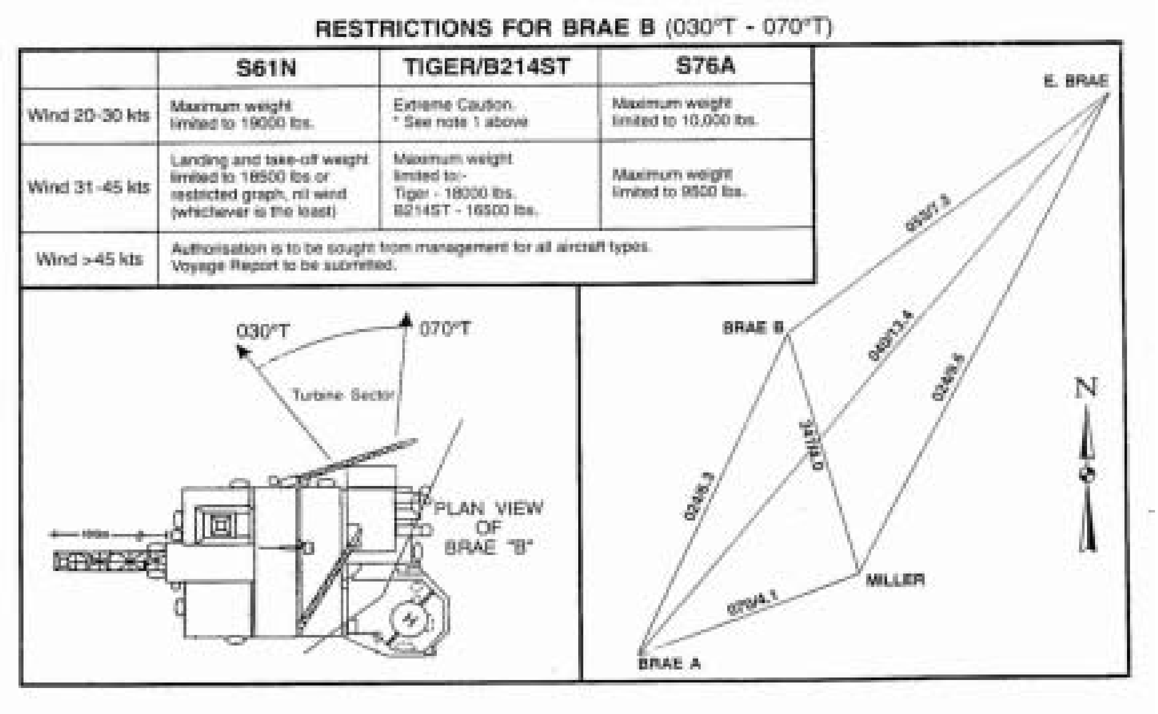


Figure 7.6 Wind Vector and Turbulence Parameter for Brae B Platform

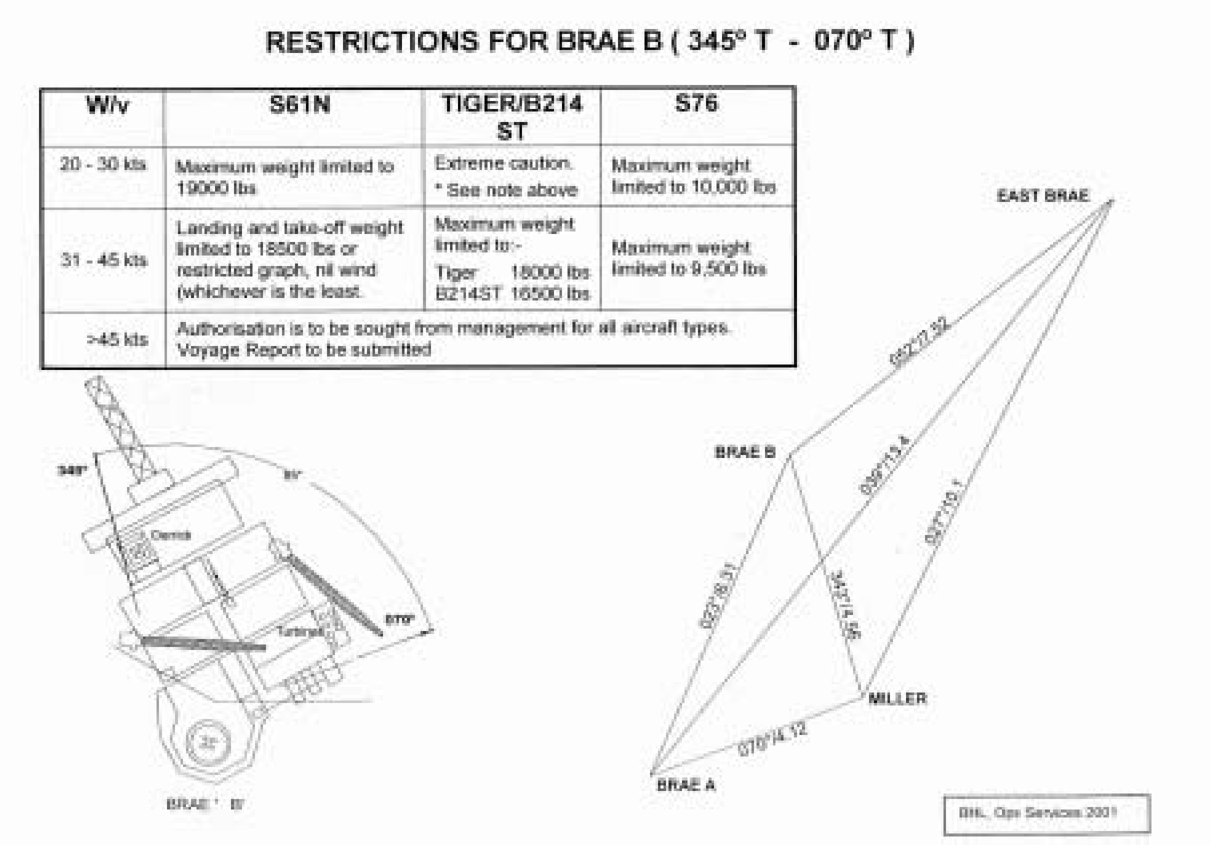


RESTRICTIONS FOR BRAE B (030°T - 070°T)

	S61N	TIGER/B214ST	S76A
Wind 20-30 kts	Maximum weight limited to 19000 lbs.	Extreme Caution. * See note 1 above	Maximum weight limited to 10,000 lbs.
Wind 31-45 kts	Landing and take-off weight limited to 18500 lbs or restricted graph, nil wind (whichever is the least)	Maximum weight limited to:- Tiger - 18000 lbs. B214ST - 16500 lbs.	Maximum weight limited to 9500 lbs.
Wind >45 kts	Authorisation is to be sought from management for all aircraft types. Voyage Report to be submitted.		

Figure 7.7 Old HLL Limitations for Brae B Platform

It was then discovered that the Brae B had been "under watch" by the BHAB helideck team and, just a few weeks before generating the data for this report, the HLL limitation was changed as the result of turbulence reports from pilots. The new limitation is shown in Figure 7.8, and includes the whole sector from 345° to 070°. The new restricted sector has also been superimposed on Figure 7.6 and it can be seen that the HOMP-generated turbulence points are much more closely aligned with this.



RESTRICTIONS FOR BRAE B (345° T - 070° T)

W/v	S61N	TIGER/B214 ST	S76
20 - 30 kts	Maximum weight limited to 19000 lbs	Extreme caution. * See note above	Maximum weight limited to 10,000 lbs
31 - 45 kts	Landing and take-off weight limited to 18500 lbs or restricted graph, nil wind (whichever is the least.	Maximum weight limited to:- Tiger 18000 lbs B214ST 16500 lbs	Maximum weight limited to 9,500 lbs
>45 kts	Authorisation is to be sought from management for all aircraft types. Voyage Report to be submitted		

Figure 7.8 New HLL Limitations for Brae B Platform

It is interesting to note that data identifying the need to modify the HLL limitation was being gathered in the HOMP for some time before the HLL was actually changed. Although in this case it merely reinforced the correctness of the change, in future it could be used as the initial trigger for change.

Figure 7.9 was generated as a control, using the Kittiwake platform as an example of an installation having no HLL limitations. It can be seen that there were no recorded encounters with medium or high levels of turbulence.

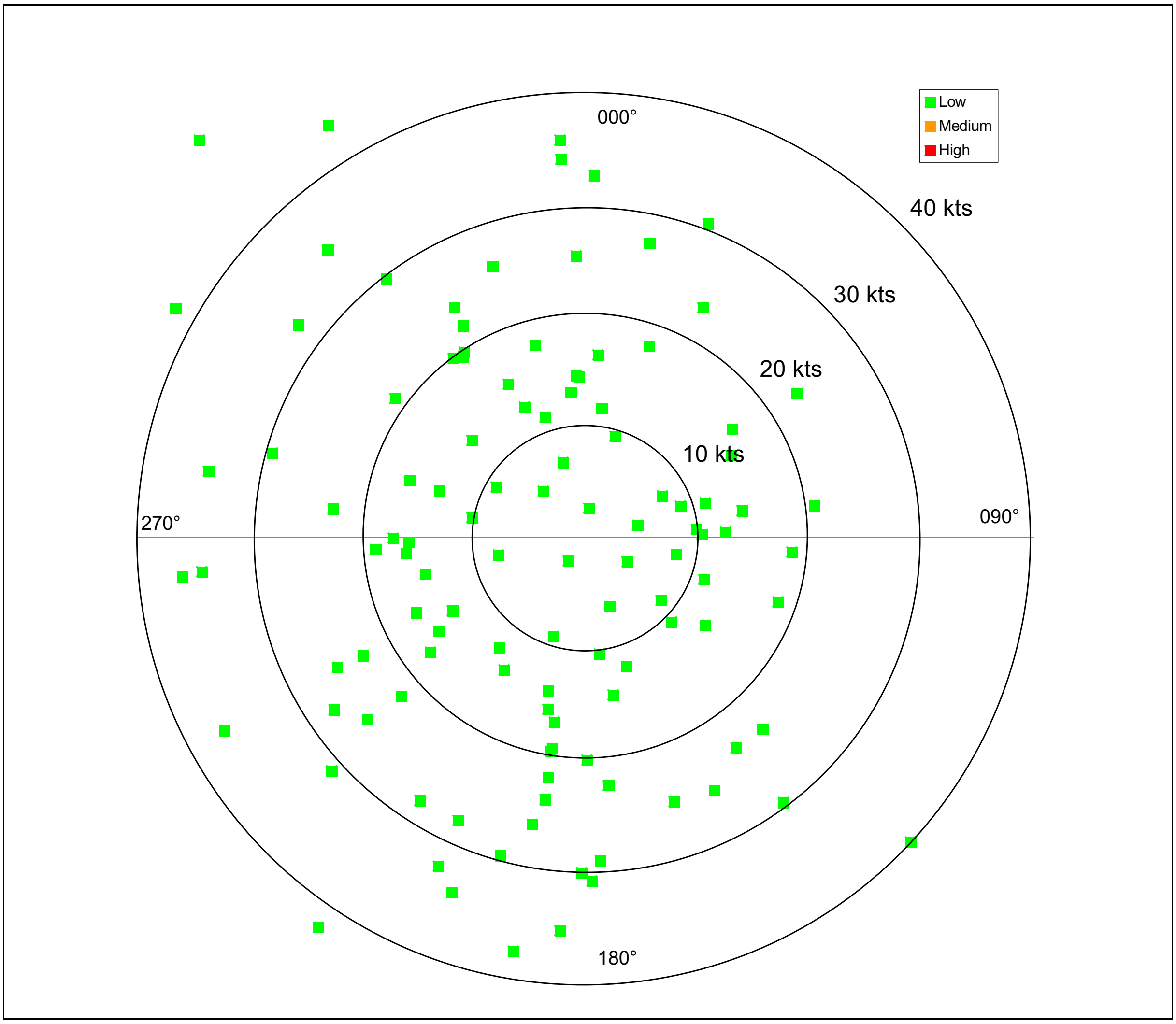


Figure 7.9 Wind Vector and Turbulence Parameter for Kittiwake Platform

The platform is shown in Figure 7.10. The helideck is placed high up on the structure with no significant obstructions to the airflow (wind) from any direction. Only the drilling derrick could possibly disturb the airflow, but it is placed well away from the helideck and has an open structure. There is also a substantial air gap between the helideck and the accommodation block underneath it. This air gap has a significant smoothing effect on the air flowing over the helideck, which would otherwise be affected by mixing with the airflow disrupted by the slab-sided accommodation block underneath.

Figure 7.10 Kittiwake Platform

7.3.2 Turbine exhaust gas

Similar plots could be created for offshore platforms to show the wind vectors where a rapid increase in OAT is detected as a result of flying through hot gas, normally from the generator turbine exhausts. Unfortunately this was not possible with the existing HOMP data as, with only one ‘maximum increase in OAT’ measurement being made per flight sector, it was not known, geographically, where this increase had occurred. To enable the measurement to be used for mapping turbine exhaust gas problems it is necessary to have separate measurements applied in the take-off and landing phases, so that a high value can be directly associated with a particular location. A modification will be made to the measurement to enable this type of chart to be generated in the future.

7.3.3 Operating differences by installation

In addition to mapping the turbulence around specific platforms, it is interesting to review HOMP data from all installations to compare operations to different platforms. Figure 7.11 shows the average value of the turbulence parameter (calculated over a number of landings) plotted against installation. In order to reduce the width of the chart, only the top 9 and bottom 10 installations are shown, which explains the apparent step change in the middle of the chart. The turbulence parameter is actually a reflection of pilot workload and so can be triggered not only by turbulence but also by high workload when trying to land on a moving deck. Therefore the vertical axis of the chart has been labelled as “average turbulence or workload”.

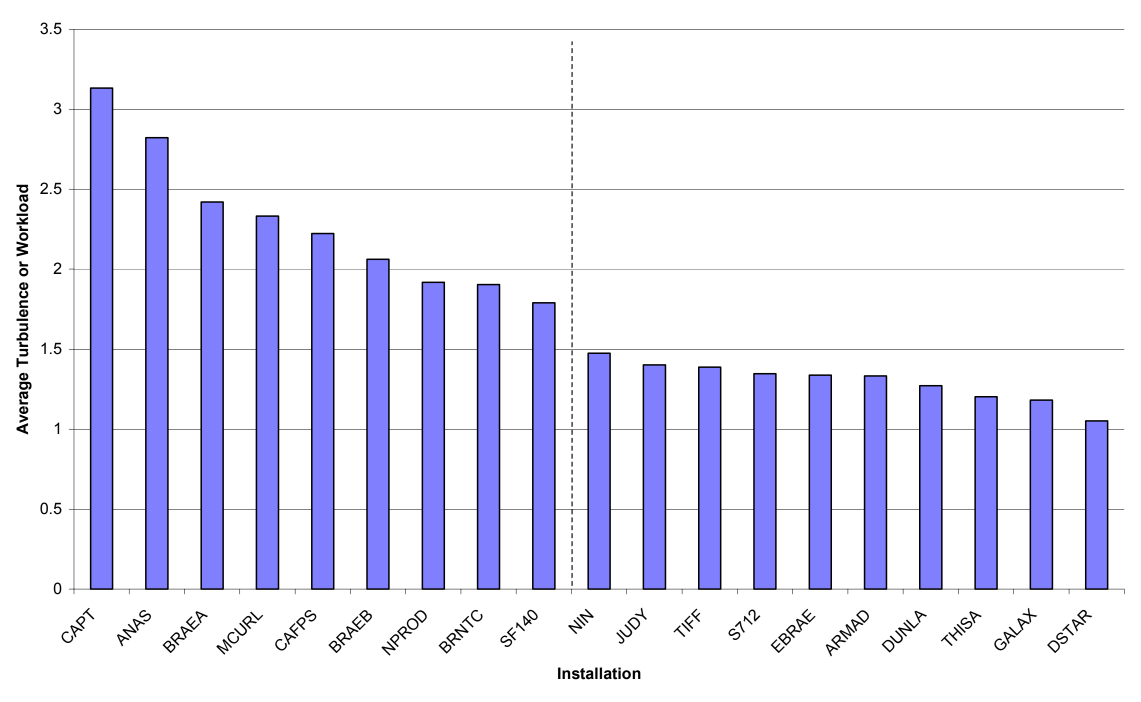


Figure 7.11 Average of Turbulence/Workload Parameter by Installation

The top 10 installations all have features that could be expected to generate high values of the parameter. The Captain platform (CAPT) has a large slab-sided structure in the immediate vicinity of the helideck, and has substantial HLL restrictions as a result. An appreciation of the problem can be gained from Figure 7.12. The obstruction is the orange/red structure near the centre of the picture.

Figure 7.12 Captain Platform

The Anasuria (ANAS) is a floating production vessel which can exhibit substantial motion and also has a problem with generator turbine exhausts blowing over the helideck. The Brae A has already been discussed as generating structure-induced turbulence in certain wind directions, and the Brae B is similar though not as bad. The Maersk Curlew (MCURL), Captain FPS (CAFPS) and Northern Producer (NPROD) are all floating storage or production ships and are substantially less stable than a typical semi-submersible drilling rig. The Santa-Fe 140 (SF140) has a mid-position deck which can be difficult to land on when the wind is coming through the structure, as Figure 7.13 illustrates.

Another measure of the safety of operating to a particular installation might be the average maximum torque required to land. If an aircraft can routinely land using less power at a particular installation, there will be more power available to deal with any contingencies such as unexpected conditions, poor piloting technique or an engine failure, than there would be at an installation which routinely requires higher power to land. Thus there is an increased probability of a favourable outcome following such a contingency. The maximum landing torque depends on a combination of factors such as the way the approach and landing is flown and the aircraft operating weight. Turbulence and downdraughts can also result in increased power demands during critical phases of the approach and landing. Figure 7.14 shows a chart of average maximum landing torque by installation, again the chart only shows the top 9 and bottom 10 installations.

Figure 7.13 Santa Fe 140 Rig

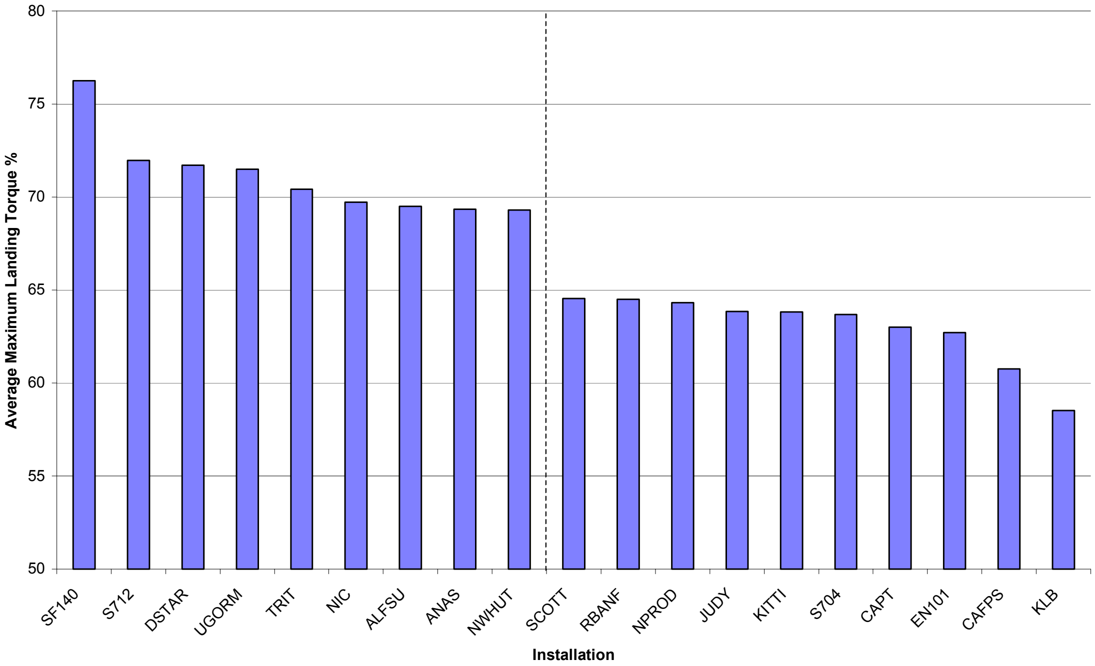


Figure 7.14 Average Maximum Landing Torque by Installation

It is interesting to note that the Captain platform is close to the bottom of this chart despite its position at the top of the previous turbulence/workload chart, which shows that turbulence problems do not result in high average power demands when landing on the platform. This is due to a low aircraft operating weight as the Captain is one of the nearest platforms to Aberdeen (being only 68 miles out), and only a limited amount of fuel is required. This is illustrated by Figure 7.15, which shows the average landing weight by installation. It can be seen that operations to the Captain are conducted at by far the lightest average weight. Work is ongoing to establish a robust relationship between landing weight and torque to enable the data in Figure 7.14 to be directly related to other factors such as turbulence and downdrafts, and the way the approach is flown.

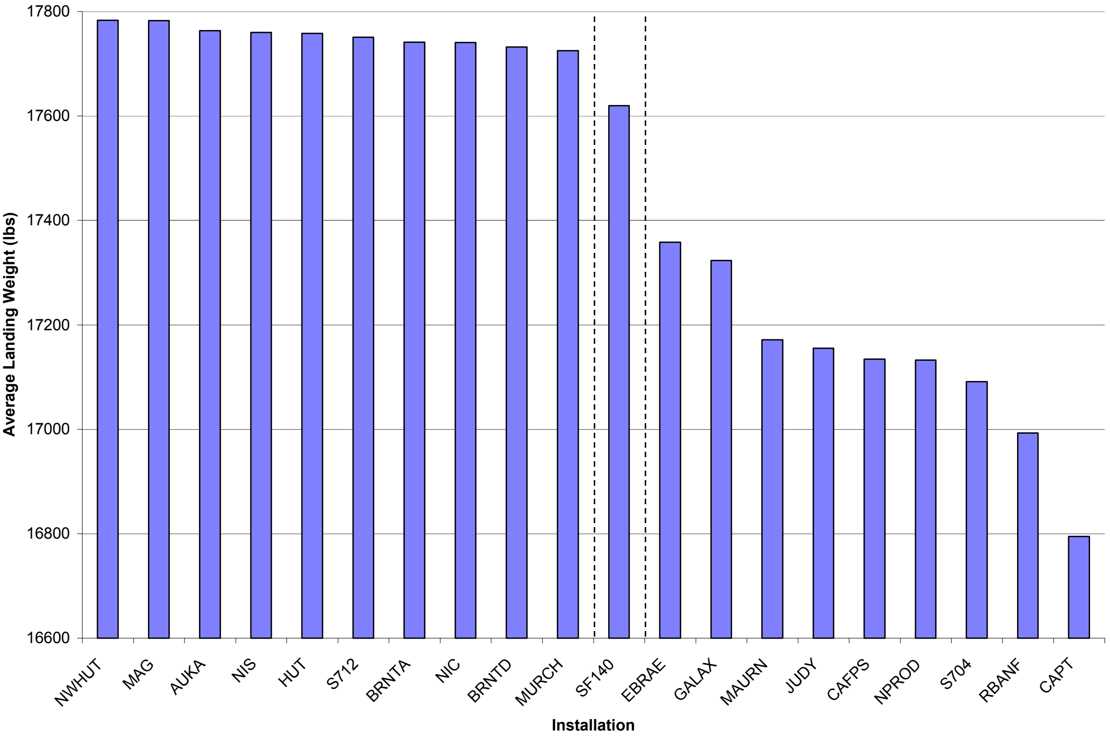


Figure 7.15 Average Landing Weight by Installation

Figure 7.15 shows the platforms with the top 10 and bottom 9 average landing weights; the Santa Fe 140 has also been included, even though it is outside the top 10. The chart shows that this installation is close to the top in terms of average aircraft landing weight. This position, combined with the high average values for the turbulence/workload parameter (the Santa Fe 140 was ranked number 9 in Figure 7.11), help to explain why the installation has the highest average maximum landing torque (ranking top in Figure 7.14).

However, an additional factor is that, with the wind blowing through the structure, and the difficulty of approaching out of wind in the Super Puma, it is difficult to achieve an optimal approach to the Santa Fe 140 (see Figure 7.13). If the approach is flown more or less straight towards the installation, there are very poor options for going around in the late stages of the approach, and serious consequences if the approach is flown too fast and the helideck overshot. Alternatively, if the normal approach technique is used and the approach flown to a point sufficiently offset laterally from the helideck to miss the structure in the event of a single-engine go-around, there is a substantial distance to be traversed after the committal point. Neither technique is very satisfactory and both can result in pilots flying a slower approach with a resultant higher torque, their normal technique having to be modified with a commensurate reduction in safety margin.

7.4 Offshore take-off and landing profile measurements

A set of offshore take-off and landing profile measurements were implemented in the HOMP trial to characterise take-offs and landings by combining measurements at specific milestones or action points. The measurements are listed in Table 4.6 in Section 4.

For Performance Class 2 helicopter operations to/from a helideck, the main consideration is the exposure time. Performance Class 2 operations are defined in JAR-OPS 3.480 as "those operations such that, in the event of critical power unit failure, performance is available to enable the helicopter to safely continue the flight, except where failure occurs early during the take-off manoeuvre or late in the landing manoeuvre, in which case a forced landing may be required". Exposure time is defined as "the actual period during which the performance of the helicopter with the critical power unit inoperative in still air does not guarantee a safe forced landing or a safe continuation of the flight". An engine failure during the exposure time can result in a deck edge strike or a ditching.

7.4.1 Offshore take-off profile

7.4.1.1 Exposure to a deck edge strike

North Sea helicopter Operations Manuals contain advice on offshore take-off profiles, derived from a Helicopter Airfield Performance Simulation (HAPS) computer model (developed by Westland Helicopters), and associated validation flight trials. The modelling defined exposure to a 'deck edge' strike, and was used to produce advice on optimum rotation heights, rotation rates and rotation angles aimed at minimising this exposure.

On every offshore take-off the HOMP measured the maximum nose down pitch angle during the take-off rotation, the maximum rotation rate, and the rotation height. The data provided information on the extent to which the Operations Manual advice was being followed.

Figures 7.16 and 7.17 show histograms of measurements of the maximum nose down pitch angle and pitch rate, respectively, during rotations on offshore take-offs. The histograms indicate that aircraft rotated to an average maximum nose down attitude of 10 to 11 degrees at an average rate of 4.5 to 5.0 degrees/second. For a normal all-engines-operating take-off, the Operations Manual advice is to rotate the helicopter up to 8 degrees nose down, but no rotation rate is specified. In the event of an engine failure after the committal point (input of forward cyclic) the advice is to rotate up to 20 degrees nose down at a rate of 10 degrees/second.

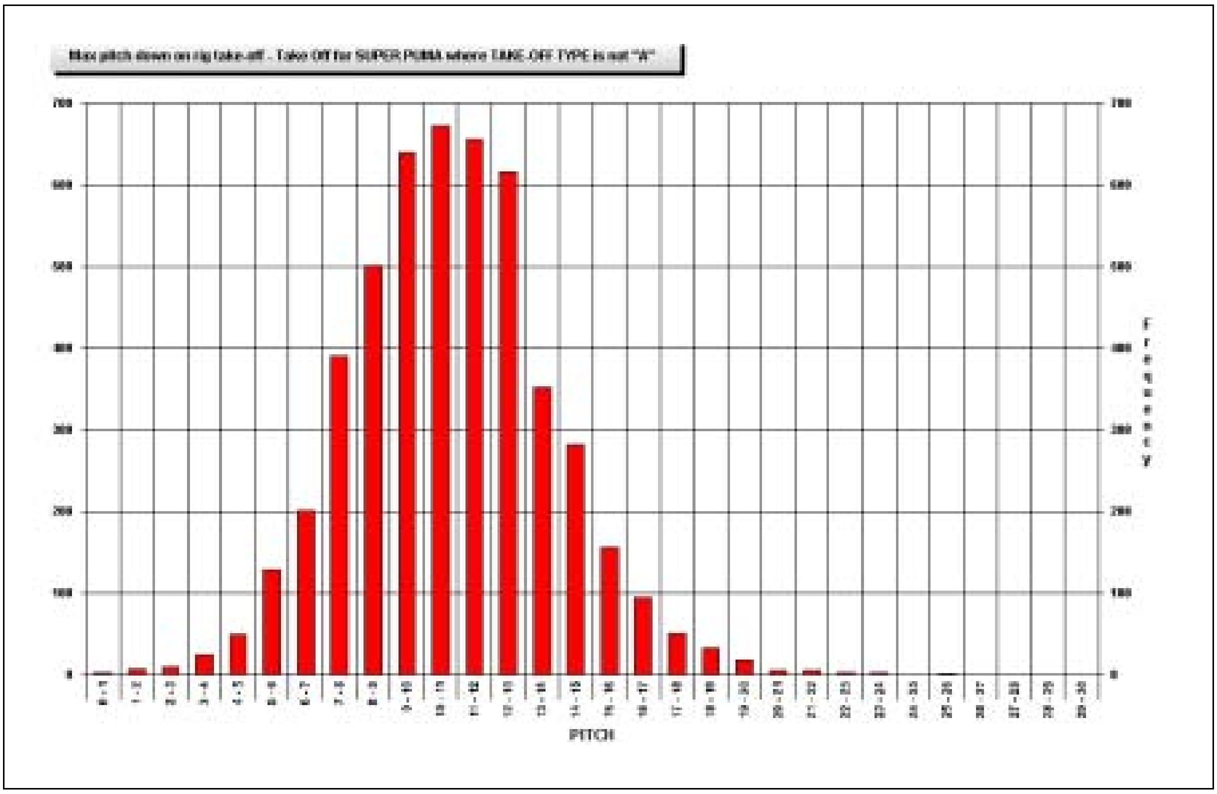


Figure 7.16 Maximum Pitch Angle

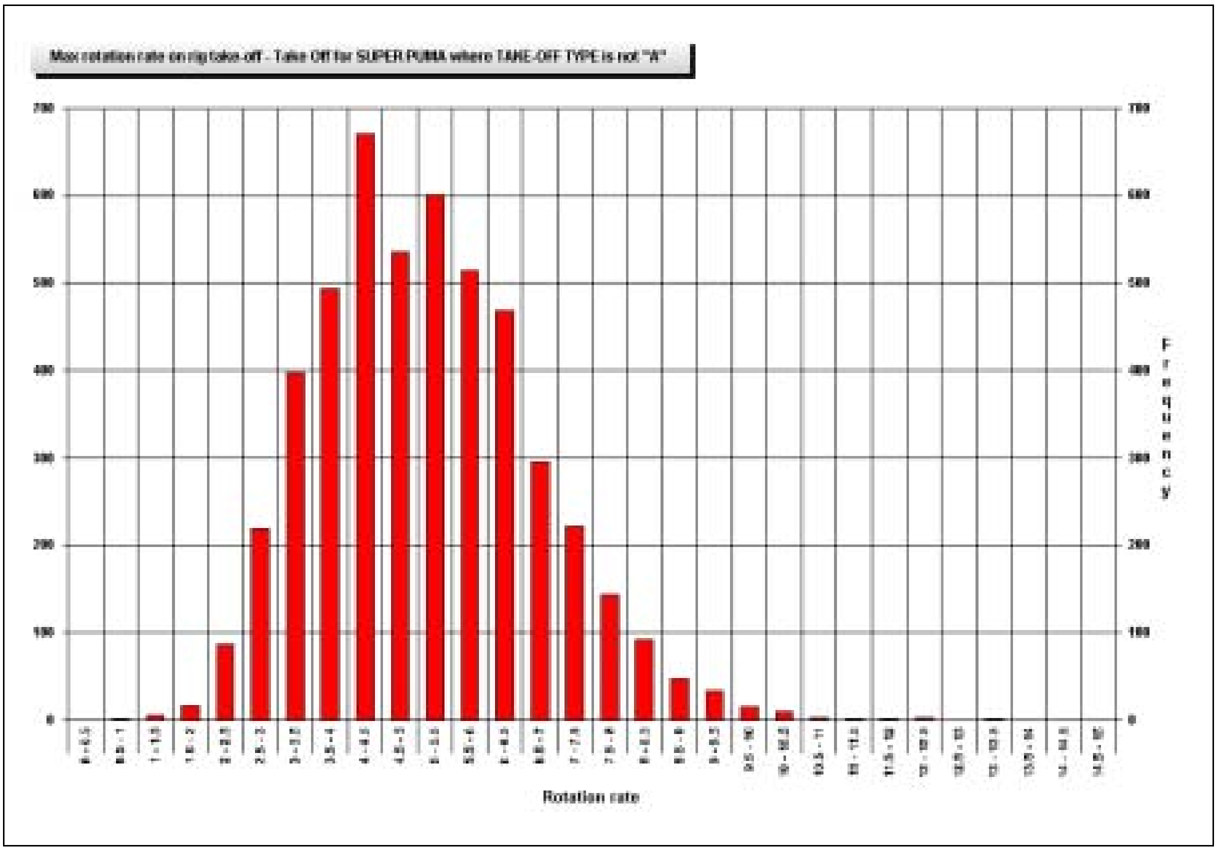


Figure 7.17 Maximum Rotation (Pitch) Rate

The optimum nose down attitude actually varies with wind speed. For light winds a larger nose down angle is needed to clear the edge of the deck and accelerate the aircraft to the fly-away speed as quickly as possible. As the airspeed starts to build, the nose down attitude can be reduced to prevent a descent starting so that the manoeuvre does not result in loss of height. For strong winds, the aircraft will already be below its single-engine hover weight, so power is not an issue. A large nose down attitude would almost certainly result in a descending flight path and a reduced angle is therefore used. The Operations Manual does not refer to wind speed for an all-engines-operating take-off, but for engine failure case it advises: "As the wind speed increases the nose down attitude on rotation may be reduced, such that at 40 knots wind speed, only approximately 8 degrees nose down is required."

The charts presented in Figures 7.18 and 7.19 show the maximum nose down angle during rotation data grouped into flights where the wind was 0 to 10 kts and 30 to 50 kts respectively. The charts showed that the average maximum nose down angle in light winds was 12-13 degrees, and in stronger winds it was 9-10 degrees. This indicated that crews were, in general, using the correct technique, employing a reduced nose down angle at higher wind speeds.

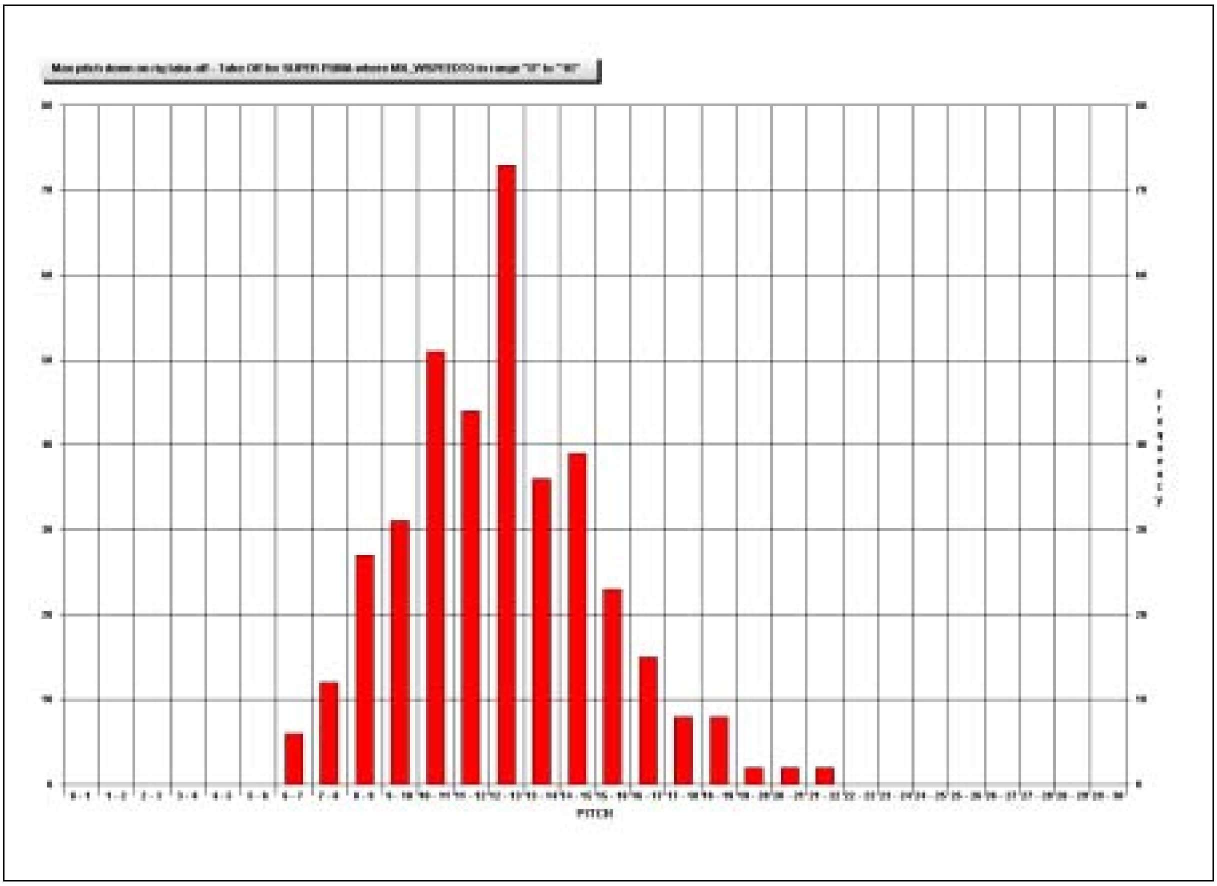


Figure 7.18 Maximum Pitch Down Angle – winds between 0 and 10 kts

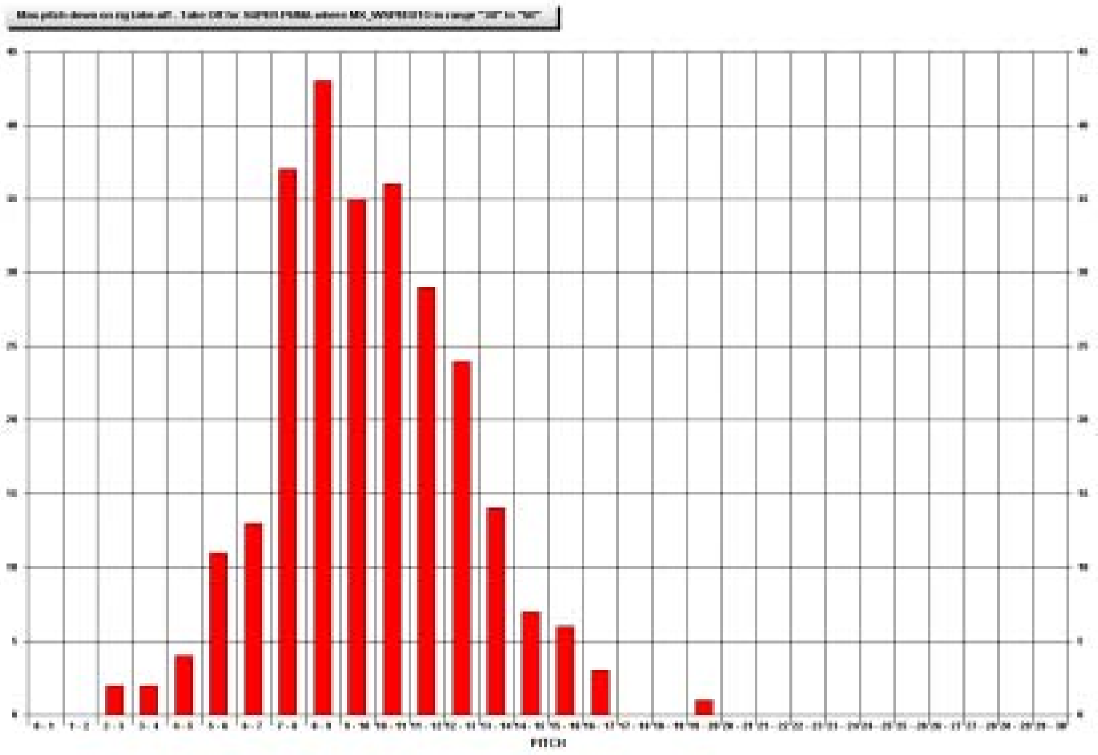


Figure 7.19 Maximum Pitch Down Angle – Winds Between 30 and 50 kts

Figure 7.20 presents a histogram showing the distribution of rotation heights on an offshore take-off (defined for the measurement as the height at which the rotation rate was a maximum). The mean rotation height was 35-40 feet. The Operations Manual advises a height of 25 feet for the committal point, i.e. the input of forward cyclic. The aircraft will still be climbing as it reaches the HOMP measurement point, which is at the maximum rate of pitching, a few moments later. The difference between the mean measurement value and the Operations Manual figure was approximately as expected, which indicated that the advice was being followed.

Some shortcomings in the take-off manoeuvre characterisation used have resulted in the falsely extended tails of the distributions. These indicate some of the problems that can be encountered when attempting to characterise a manoeuvre such as a take-off rotation from flight parameters. Investigation has shown that the very low height measurements were incorrect, as a high rotation rate could occur if an aircraft lifted off into the hover in a strong head wind. There is scope for improving the measurement to eliminate this effect. In addition, the very high values could be caused by a small increase in rotation rate well into the rotation manoeuvre. However some of the high values may well be correct because under certain circumstances it is quite reasonable to continue the vertical climb even though committal has already been passed (i.e. rejecting the take-off is no longer an option). Should an engine failure occur, the aircraft would be rotated nose down and flown away.

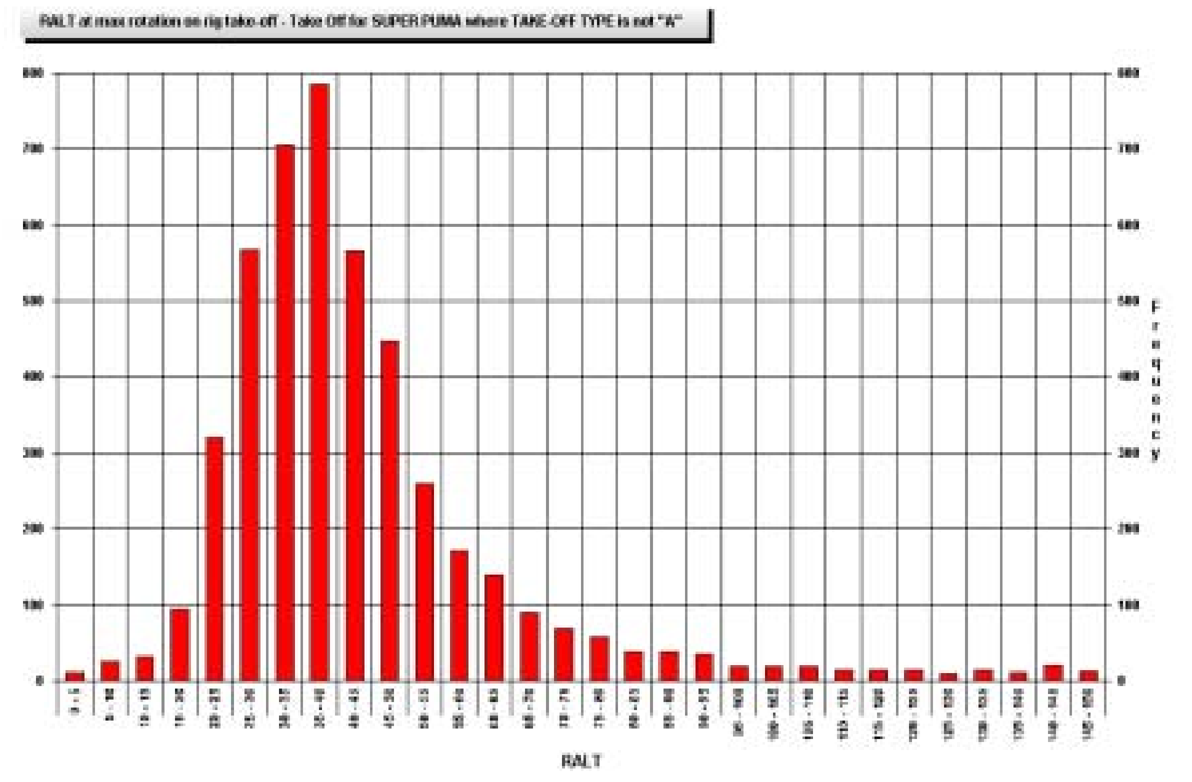


Figure 7.20 Rotation Height

7.4.1.2 Exposure to ditching

After the end of the exposure to a deck edge strike, exposure to ditching continues until adequate fly-away speed is reached. This 'exposure to a ditching' is more complex than the deck-edge case as it is dependent upon additional variables – aircraft weight, wind speed, height of helideck, clear area for drop down and pilot technique. Exposure to ditching is therefore location dependent. The subject is further complicated because the prediction from manufacturers is that exposure to engine failure ends at an air speed (Vfly-away) of between 15 kts and 35 kts, which is not within current measuring capabilities.

To provide a general indication of the maximum possible exposure time, HOMP data was used to determine the time taken to reach 35 kts airspeed from the beginning of the take-off rotation manoeuvre. From this speed, only slight or no loss of height would be required to reach minimum climbing speed Vtoss (45 kts). The results are presented in Figure 7.21. The mean of the measured maximum exposure times, as indicated by the 50% point on the cumulative percentage graph, was 4.5 seconds. This figure could be used for comparison with an 'allowed exposure' determined from engine reliability data. Most installations have a significantly elevated helideck and so, once clear of the deck edge, this height can be converted into speed by diving the aircraft, which will result in shorter actual exposure times.

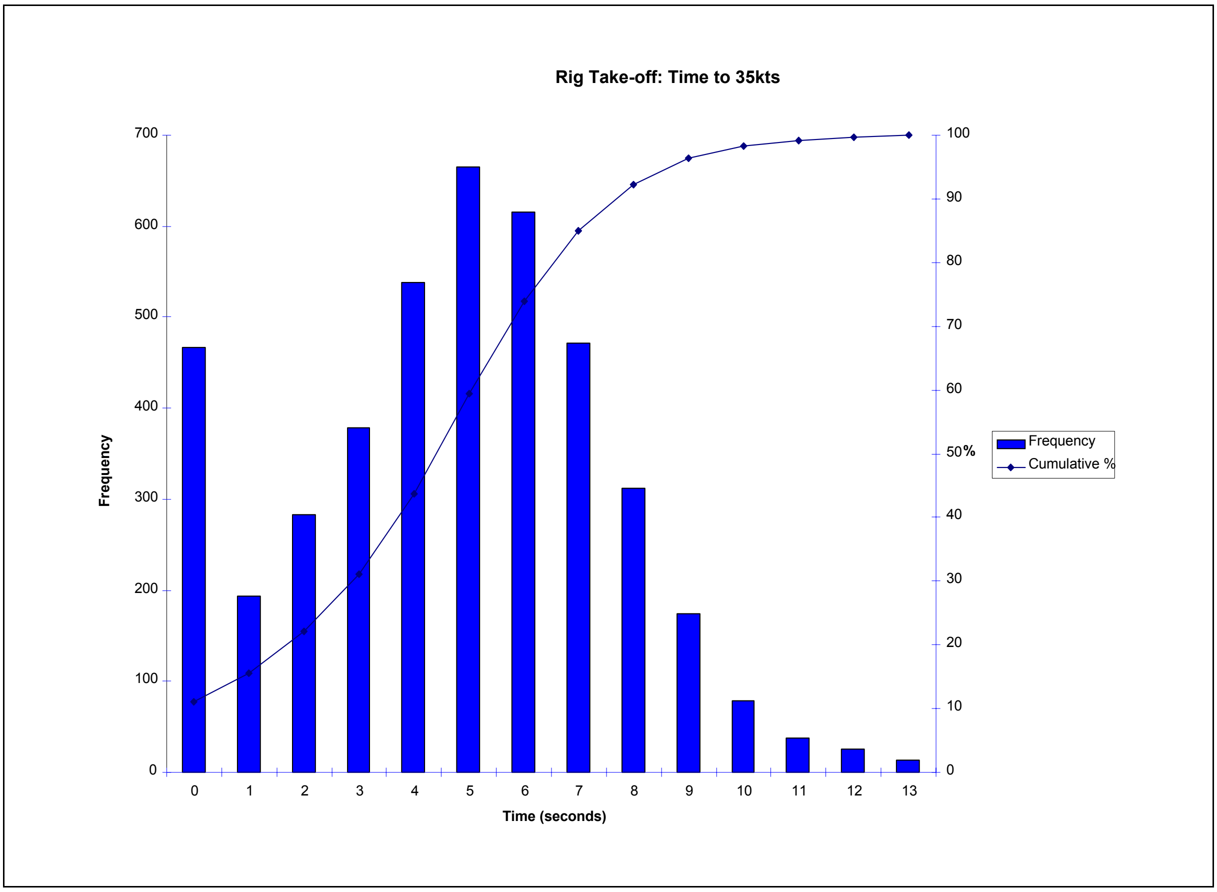


Figure 7.21 Time to 35 kts on Offshore Take-off

For completeness, Figure 7.22 shows a similar plot of the time to 70 kts. This is the best rate of climb speed (Vy) for the AS332L, and is the point at which the Performance Class 2 profile ends.

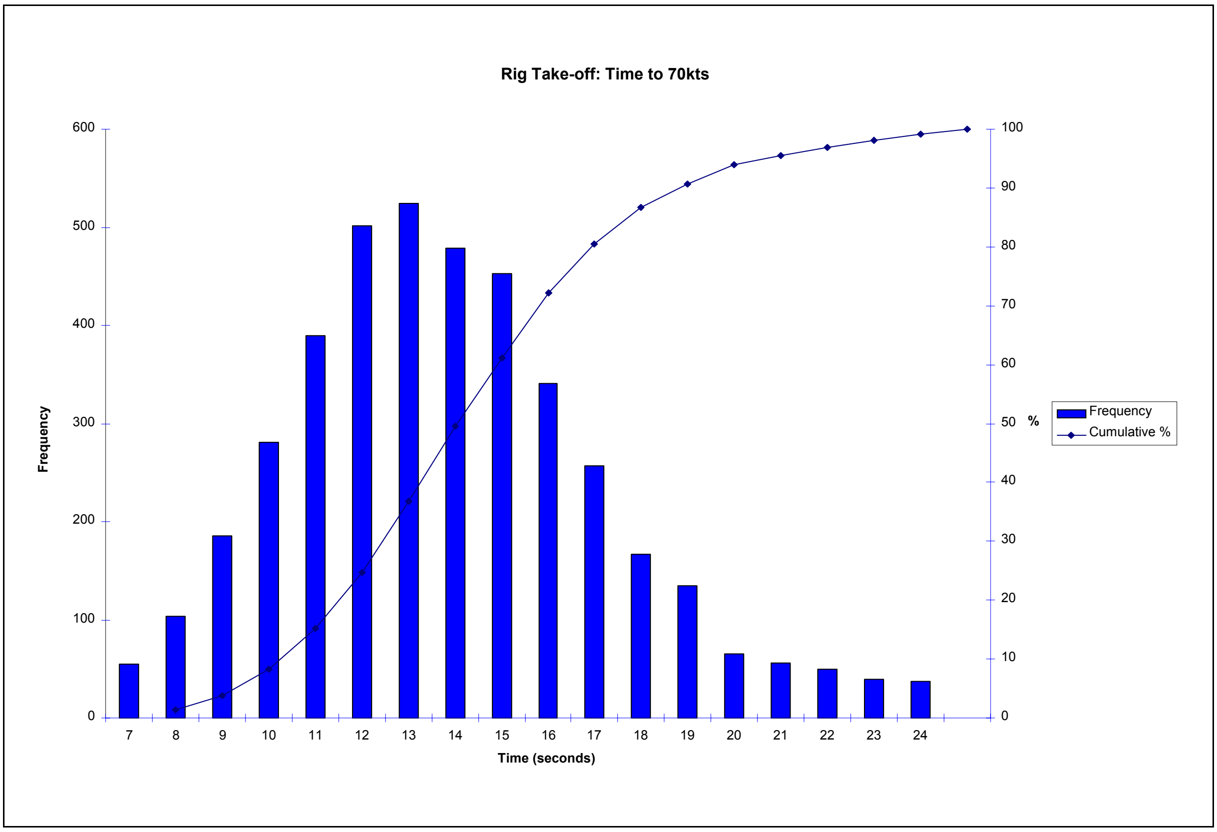


Figure 7.22 Time to 70 kts on Offshore Take-off

7.4.2 Offshore landing profile

To provide information on final approach heights and elevations in support of helideck lighting research, the CAA requested the implementation of 12 flight data measurements to generate a vertical profile of the final approach to landing. To overcome the lack of sufficient resolution in the recorded GPS latitude and longitude data the profile measurements were created by using groundspeed, heading and drift to calculate the track back from landing.

Figure 7.23 shows the angle of elevation above the helideck in degrees at a point 0.3 nm from touchdown, for night landings on offshore installations. The mean angle was approximately 5.5 degrees, which was as expected. The peak in the chart at 3 degrees was probably a result of the fact that the data included some Airborne Radar Approaches in poor weather, where the final approach might have started from as little as 50 feet above deck height. Figure 7.24 is similar but shows elevation at 0.6 nm from touchdown. The mean angle was approximately 4 degrees. This lower figure was probably due to the fact that the final approach may sometimes not have started until nearer than 0.6 nm, which could be the case in bad weather or during shuttling.

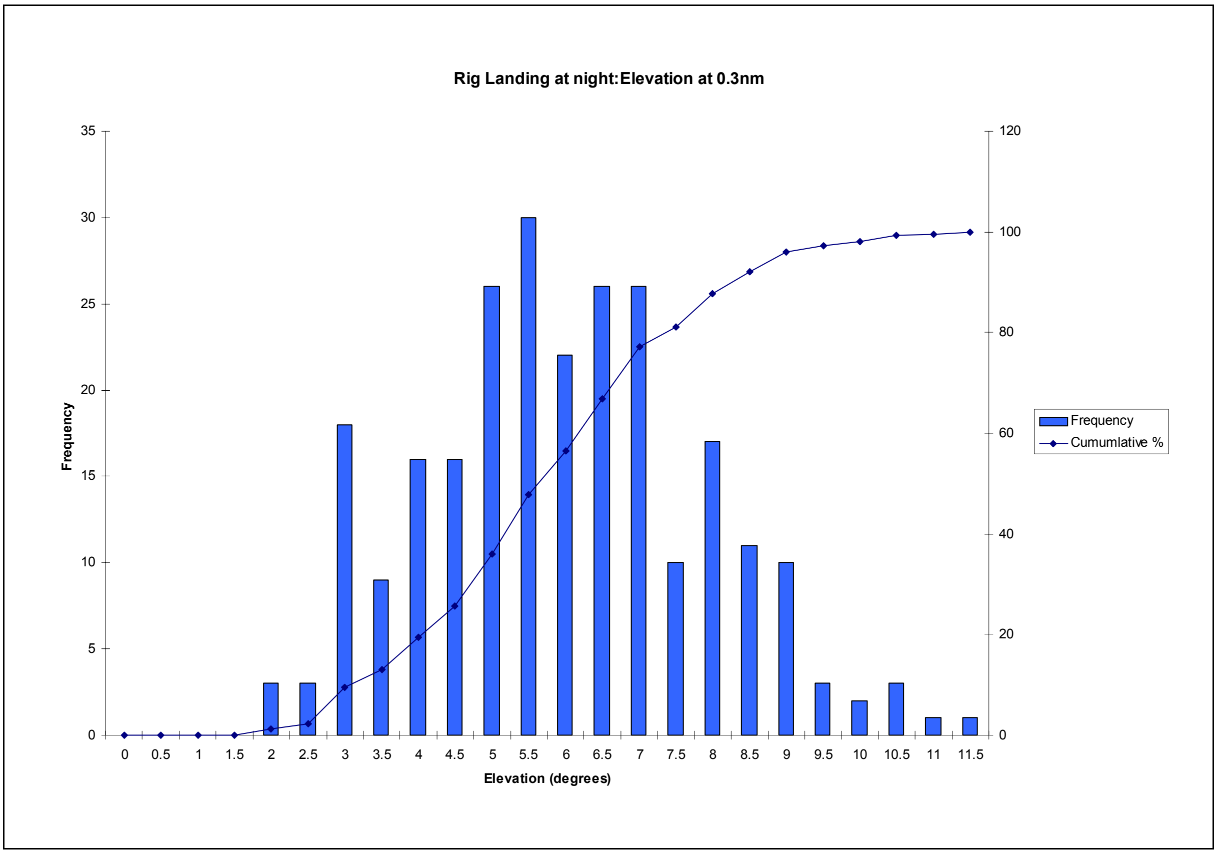


Figure 7.23 Elevation above helideck at 0.3 nm from touchdown at night

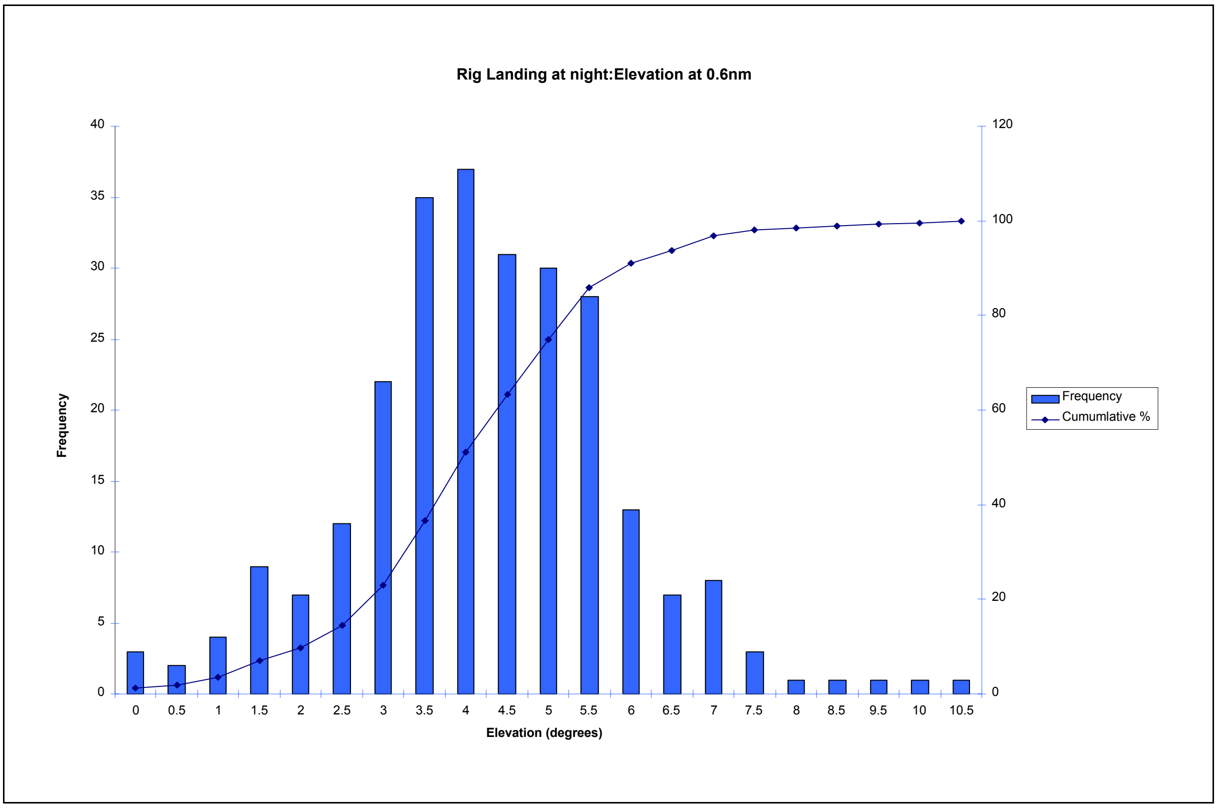


Figure 7.24 Elevation above helideck at 0.6 nm from touchdown at night

7.5 Discussion

The HOMP flight data measurements enabled the routine gathering of large amounts of operational data. The resulting information was a valuable complement to the flight data events. Whereas the events identified exceedances of predefined operational limits, the measurements could be used to identify variations in the operation caused by installation, crew or aircraft factors. These variations may be the underlying cause of events or other increased operational risks.

The general measurements provided the data needed to set effective event limits, and could be used as reference data for assessing the degree of abnormality of an event. The measurements also provided a database of information to investigate hypotheses on potential operational problems.

The HOMP trial also showed that the flight data measurements are a powerful tool for ‘mapping the helideck environment’. By routinely providing quantitative data on installations related to wind direction and speed, the measurements produced significant new information for the development and refinement of HLL entries.

The flight profile measurements generated valuable information on offshore take-offs and landings, and were used to assess risks such as single engine failure exposure. By checking that optimal take-off profiles were being flown, the HOMP measurements could be used to ensure that any such risks were minimised.

The HOMP trial demonstrated the flexibility of the measurement analysis, with new measurements quickly being implemented to generate information to support a particular investigation. A good example of this was the implementation of vertical final approach profile measurements to produce information to support the CAA’s helideck lighting research.

The trial highlighted the importance to taking care to ensure that measurements are actually providing the required information, and that results are not distorted by measurement problems, or by difficulties in characterising a particular flight manoeuvre.

Performing investigations using the database of measurements could be a time consuming exercise, and therefore resource constraints may limit the ability to make full use of it. There is scope for further enhancing the value of the flight data measurements through the application of data mining tools to the measurement database.

Section 8 HOMP Trial results – HOMP operations

8.1 Implementing the HOMP within BHL

One of the aims of the second year of the trial was to determine how a HOMP might be integrated into the existing flight safety organisation of an operator. The starting point was Figure 3.3, presented in Section 3.4, which provides a model for the basic HOMP management process.

Within the project steering committee there was a diversity of views on how the HOMP process might best be integrated into existing structures, ranging from incorporating the HOMP into the Flight Safety Department, to making the HOMP Manager directly responsible to the Chief Executive. This debate reflected the variety of different organisational structures adopted by fixed wing FDM operators. After internal discussions on how a full scale HOMP should be implemented within BHL, the following proposals were developed.

The HOMP Manager will report directly to the Head of Flight Operations because, as the AOC-holder, he is ultimately responsible for any incidents or accidents. However, to maintain crew confidentiality, the Head of Flight Operations will have no right of access to the identities of any crew members involved in HOMP-detected incidents or trends.

The HOMP Manager will maintain close links with the Flight Safety Department and will be able to discuss individual incidents with the company Flight Safety Officer. Detailed discussions of incidents, especially where an individual's history might be relevant, may require the crew's identity to be revealed to the Flight Safety Officer. Where an incident involves a fleet on which the HOMP Manager has no experience, the appropriate Fleet Representative may also be involved.

The HOMP Manager, the Flight Safety Officer and the relevant Fleet Representative will form a HOMP "inner sanctum", and will be able to discuss identified incidents. Crew identities will not be revealed outside this group except in the very exceptional circumstances laid down in Item 4 of the HOMP Management Statement presented in Appendix 1 to Section 8.

Regular review meetings, chaired by the HOMP Manager, will be held to allow a range of HOMP issues to be discussed (e.g. system updates, event trends, training issues etc.). These meetings will be on one of two levels; either involving only the "inner sanctum", in which case there may be no need for dis-identification of data, or involving other interested parties such as the Head of Flight Operations, Chief Training Captains, Base Flight Safety Representatives, and/or the Training and Flying Standards Manager, in which case all data and discussions will be dis-identified.

The proposed BHL HOMP management process is summarised in Figure 8.1, which is a slightly modified version of Figure 3.3.

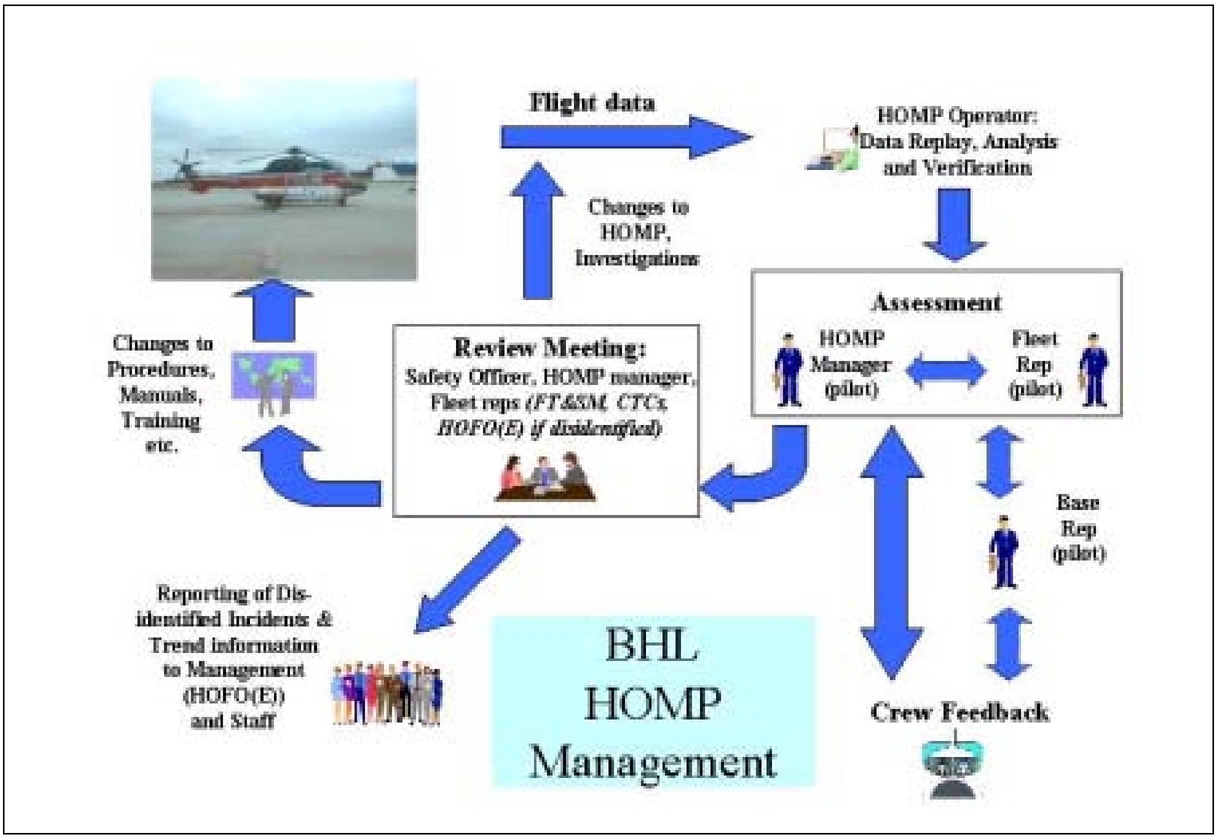


Figure 8.1 BHL HOMP Management Process

The dissemination of (dis-identified) HOMP information will be a very important part of a HOMP and will take two forms; the regular publication of HOMP newsletters, primarily aimed at flight crews, and the regular publication of HOMP event rate and trend information, primarily aimed at the Head of Flight Operations, but also made available to flight crews. Newsletters and any other lessons learned will also be passed on to other relevant operators and it is hoped that they will reciprocate.

The use of local Base Representatives will form an optional part of BHL's structure. Base Reps would be used to make contact with crew members at their base to discuss any HOMP-detected events with them, both to gather any necessary data for the HOMP Manager and to pass on any feedback. Their primary purpose would be to overcome the human factors difficulties of remotely communicating sensitive HOMP issues between strangers. The face-to-face approach from a known peer is far preferable. It is critical that Base Reps are carefully chosen to ensure that the required standards of integrity, impartiality and confidentiality are maintained.

HOMP events will be assessed for their hazard severity and, where an event or trend represents an unacceptable hazard, remedial actions must be recommended. It will be very important to ensure that any recommended actions resulting from HOMP investigations are followed up to ensure that they have been carried out. Ultimately many of these actions will be the responsibility of other personnel or departments, and the HOMP Manager is not empowered to over-rule them if they decline to enact the recommendations. In such cases, and in any case where it is decided that action is not appropriate, this should be recorded against the incident with the reasons given. It will also be necessary to monitor for any recurrence of events to ensure that any corrective action has been successful. An "audit trail" must be produced for any significant event or adverse trend identified.

The FDE module can be used in the follow-up process as it enables progress to be recorded, however it does not contain the same depth of follow-up tools as are provided in the BASIS ASR module (which is not part of the HOMP system). For a full HOMP implementation it will be necessary to formalise the follow-up process, possibly including a computer database system to facilitate retrieval of outstanding issues.

In its relationship with BHL's existing Safety Management System (SMS), the HOMP should occupy a similar position to the Flight Safety Department, in that it is independent of the company's SMS personnel, but uses processes borrowed from the SMS and passes information on trends and events back to the SMS Department. It would, of course, be subject to auditing for effectiveness by SMS personnel from time to time.

8.2 HOMP policy statements and agreements

When a full scale HOMP is implemented, it will become a formal element of the company's Safety Management System and, as such, there will be a need for a formal statement or agreement on the conduct of the HOMP from senior management.

The preferred option is to have an agreement between management and aircrew, but this would require a body representing all the aircrew to be a signatory. Because BHL aircrew are only partly unionised, it was not thought appropriate for BALPA to be this signatory and so the only option was to produce a management policy statement. After some discussions between the HOMP Manager and the Head of Flight Operations, a document was produced, but by the end of the trial this was still only in draft form and had not been signed. It will need to be formally adopted and signed before the programme expands to become company-wide. The document is presented in Appendix 1 to Section 8. Although it is in the form of a statement, with minor revision it could become an agreement between management and an aircrew union or other pilot-representing organisation.

Appendix 1 to Section 8

Draft BHL Management Statement

Helicopter Operational Monitoring Programme (HOMP)

Statement from Bristow Helicopters Ltd

1 Introduction

The management of Bristow Helicopters Ltd (BHL) recognises the significant flight safety benefits to be gained from a Flight Data Monitoring (FDM) programme. HOMP is the programme that is used by BHL.

The technology behind HOMP, like any other tool, needs to be understood and applied intelligently for it to be useful. We recognise that the key element to the success of an FDM programme is that information gained from HOMP is used correctly and not inappropriately or punitively.

The purpose of this statement is to set out the processes that will be followed during the day-to-day running of the programme, and the special procedures that might be required under extreme circumstances.

2 HOMP Philosophy

Before the advent of operational flight data monitoring programmes such as HOMP, flight data was only stored in a crash-protected recorder. This was over-written after a short time and was only downloaded and reviewed in the event of a reported incident or accident. The very large volume of data that was never reviewed, contained information on operating hazards and minor or "near miss" events. Analysing these events would provide valuable information which could be used to improve operational procedures and enhance flight safety.

The key benefit is the ability to learn from "near misses", whether due to crew errors or external factors. "Near misses" can occur with or without the crew's knowledge, and both crews and operational management will benefit from the information revealed. It is also useful to trend the occurrence rates of such events to alert management and crews alike to any areas of the operation requiring review.

HOMP also records a large number of measurements on every flight sector, and this information is used to obtain an indication of normality. It can also be used to generate information on specific factors such as the turbulence around specific platforms in specific wind conditions.

Maintaining the confidentiality of the data associated with HOMP events is a vital component of HOMP. All concerned with HOMP must ensure that the system remains non-punitive and is not seen as a "spy in the cab", and to achieve this it is important that only the minimum number of people are able to identify the crew involved in a specific incident. In HOMP, crew identities are stored in a database as encrypted numbers, and only the HOMP Manager is able to decode the number to reveal an identity. During the course of event investigations and follow-ups, if he considers it is appropriate he is permitted to reveal crew identity to specified individuals, these being limited to the Group Flight Safety Officer and the relevant

Fleet Representative and/or Base Representative, who are not at liberty to pass this on.

BHL management accept and agree that they have no access to any information or data from the HOMP system that would allow the identity of a crew member to be linked to any HOMP-detected events or trends, except under the special circumstances described in paragraph 4.

External bodies, including the charterers of our aircraft, will not be given information about particular HOMP events except with the agreement of management and with the permission of all members of the crew. However, regulatory authorities and statutory accident investigation authorities may be given access to such information as is required by statute.

3 Normal HOMP functions

The HOMP shall be run under the control of the HOMP Manager. So that he can maintain a realistic perspective on company flight operations, he shall be a company pilot who has carried out regular line flying duties within the last 3 years.

As much flight data as practical shall be gathered and processed by the HOMP system. Events detected by the system are reviewed to validate the data. Where events are considered by the HOMP Manager to be significant, they shall be reviewed by the appropriate Fleet Representative, who will assist the HOMP Manager in determining whether the crew need to be contacted. If so, the HOMP Manager will invoke the appropriate procedure. Events may also be reviewed at routine meetings attended by the HOMP Manager, the Group Flight Safety Officer and the relevant Fleet Representative.

Review meetings will also be held with other members of staff such as the Head of Flight Operations, the Flying and Training Standards Manager, and Chief Training Captains but, in this case, no information that could lead to the identification of crews shall be revealed.

If the crew are to be contacted, this shall be done by the HOMP Manager, Group Flight Safety Officer, the appropriate Fleet Representative or appropriate Base Representative, as determined by the HOMP Manager. The contact may take any form, such as face-to-face (which is the preferred means), by telephone, letter or email. The purpose of the contact is to further investigate and validate the event and, if appropriate, to give feedback on the crew's actions and allow them to learn from any mistakes made. If appropriate, and not already done, the crew will be encouraged to file an ASR.

Where there might be considered to be an element of crew error, both crew members will be contacted as near simultaneously as reasonably practical and no data will be given to a crew member until both have been contacted. Crew members will be advised that they should not divulge the name of their colleague in any discussions of the event with third parties.

A HOMP newsletter shall be produced from time to time, describing events and trends that have occurred, in a way that does not identify the individuals involved. The permission of crews involved shall not be required for this activity.

It may be appropriate to send identified HOMP data to other Bristow employees or external companies to assist in the investigation of incidents. In this case, the permission of both crew members shall be obtained before this takes place.

The HOMP Manager may occasionally consider it appropriate to try to direct routine training towards remedying a particular problem that an individual is having. This will only take place following discussion with the individual concerned and after the permission of the individual is obtained. The Training Captain programmed to give the training may then be informed of the individual's name and the nature of the problem. This information shall be passed informally and in confidence, and it shall not go into the individual's training records.

Following an incident or accident that has been detected solely by normal (non-HOMP) means, normal HOMP procedures will be followed and the HOMP data shall not be available to company investigators unless at least one of the following applies:

a) All crew members give their permission.

b) The company decides to download the aircraft's FDR, and the relevant flight data is successfully recovered.

c) The HOMP data is required by the AAIB.

If, in the HOMP Manager's opinion, the event is of a purely technical nature, relevant data may be passed to engineering to assist with diagnoses.

An illustration of the company's HOMP organisation is shown in Annex 1 (not shown here, but identical to Figure 8.1 in Section 8.1 of this report).

4 Procedures to be followed during exceptional circumstances

Although the company recognises that confidentiality is a vital element of HOMP they, and all flight crew, also have a duty of care to the company's passengers. Therefore under extreme circumstances it may be necessary to consider the removal of confidentiality of the name of an individual or crew. This might occur following an incident where gross negligence has occurred, or following a series of incidents where no progress has been made to reduce the likelihood of recurrence. The initiative for the removal of confidentiality may come either from the Head of Flight Operations, the HOMP Manager or the Group Flight Safety Officer.

Under these circumstances a meeting shall be convened to make the decision, chaired by the HOMP Manager and attended by the Group Flight Safety Officer. The pilot concerned will be invited to send a representative, either a friend or a member of the BALPA company council, to attend the meeting if he wishes. The meeting shall not be attended by company management nor by the pilot in question.

Following examination of any relevant factors, the meeting shall decide the outcome of the application to remove confidentiality by a majority vote of all attendees. In the event of a tie, confidentiality shall not be removed. The chairman of the meeting will give written reasons for its decision to the initiator and the pilot concerned.

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Peter Barnes Head of Flight Operations, Europe	Neill Osborne Director, Europe

Section 9 HOMP Full Scale Implementation

This section briefly considers the requirements for a full scale HOMP implementation and estimates the associated costs.

9.1 HOMP requirements

9.1.1 Equipment

Equipment requirements are summarised below; detailed information on requirements can be obtained from the HOMP trial equipment description in Section 4.

- PC card QARs to provide ready access to aircraft flight data (it is assumed that the existing aircraft flight data acquisition units are all provided with auxiliary outputs for a QAR interface).
- Aircraft modification kits.
- PC cards for the transferring of flight data from the aircraft to the ground (3 cards per aircraft should be provided).
- Ground based hardware, including a high specification data analysis PC with a large monitor, large capacity hard disk, A3 colour printer and PC card reader. Also data download PCs for remote bases, and portable PCs to support away from base operations, all with PC card readers. It is important that the data analysis PC is dedicated to the HOMP, and not used for any other purpose.
- Data transfer and archive media. If possible, company networks or the Internet should be used for the electronic transfer of data from remote bases.
- Data replay and analysis software for the HOMP analysis centre. This software should provide comprehensive HOMP data analysis and management facilities, performing both event and measurement analyses, and incorporating the tools for the review and analysis of data and data trends. Additional copies of the software might be required to provide a data analysis capability for aircraft detached away from base for a time.

9.1.2 Facilities

Office facilities are required, with telephone, email, and access to operations databases, weather information etc. There should be enough space for discussions between crew and the HOMP Manager, as well as for any full-time HOMP staff. Secure facilities must be provided for the storage of all HOMP data.

9.1.3 Organisational structures and procedures

It is vital that well defined HOMP organisational structures, processes and procedures are developed and implemented. Any programme operating without these will only have limited success. Models for the HOMP procedures are presented in Sections 2 and 8 of the report. Additional guidance can be obtained from References [4] and [5].

9.1.4 Personnel

Numbers of personnel will depend on the size of the operation. A HOMP may include a dedicated technician who would be responsible for the daily tasks of downloading and processing data, eliminating obviously spurious events, producing trends and reports and interacting with software developers. He would need to have some computer skills and knowledge of flight operations, but need not be an expert in either.

A HOMP Manager will be required, and he should be a current pilot, ideally a training captain. If no technician is provided, more time would be required from the HOMP Manager and he would need some computer skills. Another approach would be to contract out the routine downloading and replay tasks to a specialist third party. While this would require less time and computing skills from the HOMP Manager, he would still retain full responsibility for the programme.

Additional input will be required from a Fleet Representative for each of the fleets included in the HOMP to address fleet-specific issues.

It is very important that the HOMP is properly resourced, a failure to adequately resource the programme will prevent it from being effective. Procedures must be put in place to provide adequate cover during any periods of absence of key HOMP personnel.

9.1.5 Agreements

It is strongly recommended that a written agreement between aircrew and company management be established before the programme starts. This agreement should clearly state the objectives of the HOMP, and that the programme is non-punitive and focussed on providing positive feedback. It should be based on the requirement for confidentiality of aircrew identity, and management and aircrew must indicate that they have placed their trust in the HOMP Manager’s discretion. In the case of charter operations, management must also ensure that their clients are aware that they have no right of access to crew-identified information under any circumstances.

The agreement should make provision for the removal of anonymity only under the most extreme circumstances or when all other avenues have failed, and the HOMP Manager is likely to be the only person in possession of sufficient information to make that decision. The information contained in Sections 2 and 8 of the report can be used as the basis for an agreement.

9.2 Estimated HOMP implementation and operating costs

This section estimates costs for the implementation and operation of a HOMP. The cost data is only intended to be used for assessing the rough order of magnitude of the HOMP costs.

9.2.1 Assumptions

Costs are estimated based on the following assumptions:

- Operators have total fleet sizes of 10, 20 or 40 helicopters
- The operator typically has 3 helicopter fleets (e.g. S61, AS332, S76)
- The operator has one HOMP data analysis centre
- The operator typically has one main base and other satellite bases

9.2.2 Start-up costs

9.2.2.1 On-aircraft system

The PCMCIA Card Quick Access Recorder (CQAR) costs were estimated by BAE Systems. It is assumed that there is a 20% spares holding of CQARs (e.g. 12 CQARs for a fleet of 10 aircraft), that PCMCIA cards cost £125 per card, and that there are 3 cards per aircraft.

The aircraft modification cost has been estimated by BHL and will cover design of the modification, production of mod kits and embodiment of modification. If BHL produced the modification for the AS332, S-61, S-76 (various models) and AS365, and made kits for a total of 70 aircraft, the design, kit manufacture and installation would be in the order of £1,200 per aircraft.

The on-aircraft system costs for the different total fleet sizes are shown in Table 9.1, with the total costs rounded up to the nearest £5k.

Table 9.1

Fleet Size	CQARs	PCMCIA Cards	Aircraft Modification	Total Cost
10	£71,000	£4,000	£12,000	£90,000
20	£142,000	£8,000	£24,000	£175,000
40	£256,000	£15,000	£48,000	£320,000

9.2.2.2 Ground-based system

It is assumed that there is one main analysis PC, 2 satellite base PCs for remote data download and transfer to a central analysis facility, and 2 laptop PCs to support data collection from aircraft detached away from base for a time. Including media, a total cost of £8,000 has been estimated for the ground based hardware.

HOMP software (excluding aircraft specific configuration) and system configuration costs have been estimated by BA and ES-S and assume that the HOMP system will support 3 helicopter fleets. Software costs will vary according to the number of helicopter fleets, and for 3 fleets costs are estimated to be in the order of £50,000.

The configuration task includes configuring decode equations, reviewing events and measurements with the operator, configuring them and testing the configured system. Configuration costs are estimated to be £10,000 for one helicopter fleet and £20,000 for 3 fleets.

The total ground-based system costs, rounded up to the nearest £5k, are therefore estimated to be in the region of £80,000. If there is a requirement for a second copy of the HOMP software to enable data analysis at another base, an additional software cost of £10,000 should be included for this.

9.2.2.3 System introduction

The operator's personnel who will have responsibility for managing the HOMP would be expected to implement the programme (defining procedures, put agreements in place etc). The Flight Safety Officer would also be expected to have some involvement in this process.

The same operator's personnel would be responsible for commissioning the HOMP system, but an allowance of £10,000 could be made for external training and support during a period of system commissioning when the data analysis is tuned to control event rates etc.

9.2.3 **Operating costs**

9.2.3.1 Programme operation

It is assumed that the HOMP is run 'in house' by the operator, and costs will primarily be determined by personnel requirements. For a total of 30+ aircraft in 3 fleets, these are estimated by BHL to be:

- One full-time technician.
- One part-time HOMP Manager, allocating one-third of his time to the HOMP.
- One part-time Fleet Representative for each fleet, allocating one-quarter of his time to the HOMP.
- The Flight Safety Officer, allocating one-quarter his time to the HOMP.

The manpower costs for operating the HOMP are estimated to be in the order of £130,000 per annum.

9.2.3.2 Software maintenance and support

Assuming that the cost of software maintenance and support is 20% of the purchase price per annum, this cost would be approximately £10,000 a year.

9.2.3.3 System management

System management tasks can include the following items (N.B. some or all of these might be included under the heading of "programme operation"):

- Management of software updates.
- Management of system configuration for events and measurements.
- Periodic system tests to check that all events and measurements are working.
- Periodic review of the events database to identify events not triggering or triggering too frequently.
- Managing special HOMP investigations and analyses.
- System configuration and document control.

The above tasks could be performed ‘in-house’ by the operator, or performed with third party support. If some third party support is assumed, an additional allowance of £10,000 per annum could be included for this.

9.2.3.4 Start-up cost comparison with HUMS/FDR

The total HOMP start up costs shown in Sections 9.2.2.1 and 9.2.2.2 are summarised in Table 9.2, in which per-aircraft costs are also calculated.

Table 9.2

Total Fleet Size	**On-aircraft System**		**Ground-based System**		**Combined Total**	
	Per Aircraft	**Total**	**Per Aircraft**	**Total**	**Per Aircraft**	**Total**
10	£9,000	£90,000	£8,000	£80,000	**£17,000**	**£170,000**
20	£8,750	£175,000	£4,000	£80,000	**£12,750**	**£255,000**
40	£8,000	£320,000	£2,000	£80,000	**£10,000**	**£400,000**

It can be seen that the total per-aircraft HOMP start-up costs are in the range £10,000-£17,000. This compares with a rough order of magnitude per-aircraft start-up cost of £250,000 for a complete HUMS/FDR installation (comprising the complete retrofit kit and the installation work). It is recognised that a significant percentage of this cost related to the fitting of the FDR which was a mandatory requirement. Because of the synergy between the systems, the opportunity was taken to install a HUMS at the same time and, as a result of its proven safety benefits, this system has now been mandated for the larger helicopters in the UK.

The existence of an FDR is an essential pre-requisite for a HOMP. With its relatively low incremental costs, the HOMP benefits from the initial investment made in the FDR system, whilst being able to unlock significant additional safety benefit inherent in this.

Section 10 Conclusions

10.1 Conclusions related to the objectives of the HOMP trial defined in Section 3.2

Objective 1: Establish how best to monitor helicopter flight operations.

Comprehensive sets of helicopter flight data events and measurements were developed and then refined throughout the operational phase of the trial (Section 4.4). The results demonstrated that they successfully monitored helicopter flight operations (Sections 5.4, 6 and 7).

Objective 2: Evaluate the safety benefits of this monitoring.

Although the trial HOMP implementation was limited to five aircraft it was extremely successful in identifying significant safety issues, and the operator was able to take corrective and preventative measures to address them (Section 6.3). The trial clearly demonstrated that the HOMP is a practical and cost effective flight safety tool, able to bring about improvements in flying practice, training, operating procedures and coping with the operational environment.

Objective 3: Evaluate the tools and equipment required for a HOMP and eliminate any technical risks associated with these.

The CQAR data recorders were very reliable. A total of approximately 11,500 hours of data was gathered during the trial and a data collection rate of 90-95% was achieved, which is comparable to the best current fixed wing systems (Section 5.2). The data replay and analysis software performed well, and functionality was further enhanced as a result of experience gained during the trial (Section 5.3).

Objective 4: Establish and evaluate a programme management strategy.

Aided by direction from the integrated project team, the operator was able to manage and operate the HOMP effectively. Management issues were identified and addressed (Section 5.5) and, based on the trial experience, a suitable HOMP management strategy was developed (Section 8.1).

Objective 5: Determine the workload a HOMP would impose on a typical helicopter operator.

The trial was run successfully by the BHL HOMP Manager (a senior training captain) on a part-time basis. Typically one hour per day was spent on routine tasks with additional time being required during the follow-up of specific events. This was regarded as acceptable by BHL. There was some conflict between HOMP activities and flying duties during busy operational periods, and the trial highlighted the importance of properly resourcing the programme (Section 5.5).

Objective 6: Establish agreements between aircrew and management to ensure that the identity of aircrew is protected, and the focus is on positive feedback.

A statement of intent was issued by the HOMP Manager at the start of the trial but, as yet, no formal agreement has been put in place between management and crew. However, aircrew response to feedback has been positive. A draft policy statement has been developed and included in the report as the basis for a future aircrew agreement (Section 8.2).

Objective 7: Further expose industry to the concept of a HOMP, enabling a more informed consideration of its full scale implementation.

A number of briefings have been given along with conference papers and magazine articles to promulgate the results of the trial. As a result, UKOOA have committed their members to require the implementation of HOMP on all FDR equipped UK public transport helicopters operating over the UK Continental Shelf.

10.2 Additional conclusions

1 The trial successfully applied the concept of Flight Data Monitoring (FDM) to FDR-equipped helicopters. Helicopter flight data currently remains locked away in a crash protected recorder until after an incident or accident has occurred. The trial demonstrated a near term, low risk and cost effective method of making pro-active use of this flight data to bring about a significant improvement in the safety of helicopter operations.

2 The HOMP detected a wide variety of events, and the follow-up of them identified a range of operational issues relating to pilot knowledge and skill, gaps in the training system, cockpit resource management, operating procedures and the offshore environment. A number of the most notable events detected could be related to previous North Sea helicopter incidents and accidents (Section 6.3). In addition, by being able to monitor the occurrence rate of particular events, the event trend analysis enabled operational risks to be more accurately assessed. (Section 6.2).

3 BHL implemented effective processes for investigating events, following them up with aircrew when necessary, and closing the loop by providing positive feedback and initiating appropriate safety related actions. A range of feedback mechanisms were successfully utilised, such as confidential pilot debriefs, prompting the raising of Air Safety Reports, contact with safety and training staff, and issuing newsletters. Aircrew were receptive to confidential feedback on significant events and also, on occasion, requested information from the programme (Section 5.5).

4 Although by the end of the trial 90% of the events being generated were still classed as nuisance or false events, this apparently high rate was not a problem owing to the low total number of events being generated and the quickness with which nuisance or false events could be identified (Section 5.4). The number of nuisance events accepted is largely a matter of choice, event limits could be changed to reduce these, however events pointing to significant occurrences could then be missed.

5 The analysis of flight data measurements from every flight was shown to be a powerful and flexible tool for assessing information on routine offshore operations that had not previously been available (Section 7). This was useful in setting event limits and identifying operational variations that may reveal the underlying causes of events. Some of the most significant new information generated in the HOMP trial related to ‘mapping of the helideck environment’, i.e. identifying and characterising problems such as the effects of turbulence on operations. Flight profile measurements also generated useful information for the assessment and minimisation of risks associated with offshore take-offs and landings.

6 The helicopter trial has proven very successful as evidenced by the pro-active response of Industry in advance of any regulatory action. While no such action is currently proposed, it may form a natural development of the present ICAO initiative for fixed-wing operations Flight Data Monitoring. The trial has provided excellent material to support the case for any future action in this regard.

7 This report contains information and guidance material on the implementation, management and operation of a HOMP. Although it relates to a helicopter FDM programme, many of the lessons learned and issues addressed are common to both helicopter and fixed-wing FDM. It will therefore be of value to any fixed wing operator implementing a FDM programme, particularly smaller operators with fleets of regional jets or turboprop aircraft.

Section 11 Recommendations

The following recommendations are made:

1 Helicopter operators should implement a HOMP on all FDR-equipped commercial air transport helicopters, incorporating the programme into their existing safety management systems.

2 The CAA should make representations to ICAO to have the existing initiative on Flight Data Monitoring programmes for fixed wing aircraft extended to include FDR-equipped commercial air transport helicopters.

3 The CAA should utilise the experience gained from the HOMP trial to provide assistance to other operators planning to implement a HOMP (e.g. in the form of direct support, consultancy, training or guidance material), to ensure that effective programmes are established. In particular, using reference [4], this report and other relevant publications as source material, the CAA should consider producing guidance material (to include a generic event set) on the implementation of a HOMP in the form of a CAP.

4 In respect of HOMP improvement CAA should, together with the helicopter operators:

- develop and evaluate a methodology for the automatic allocation of event severity levels, with the application of context dependent weighting factors to events.
- develop data mining tools for the efficient analysis of HOMP event and measurement databases, e.g. to automatically detect event trends and to identify abnormalities in measurement data prior to the triggering of any events.
- complete development of additional capabilities, e.g. provision of an accurate low airspeed measurement capability, and turbulence related pilot workload measurements from other CAA research projects.

5 In respect of HOMP implementation and operation, helicopter operators should:

- standardise the HOMP events used by different operators where possible to aid the sharing of lessons learned.
- continue to refine the HOMP events to maximise the safety benefits of the programme, and optimise the balance between detecting the widest possible range of operational risks and minimising the nuisance event rate.
- continue to refine the HOMP measurements to maximise their accuracy in characterising different aspects of the operation, and to develop further analysis capabilities, e.g. thermal mapping of the offshore environment.
- develop capabilities for the automatic monitoring of data collection performance to rapidly identify any loss of data and hence maximise the data collection rate.
- implement additional capabilities as they become available to further expand the safety benefits which can be achieved, e.g. by adding an accurate low airspeed measurement capability, and turbulence related pilot workload measurements.

Section 12 References

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