AN APPRECIATION OF WHERE HUMAN ACTION RESULTS IN ERRORS PREJUDICIAL TO THE SAFETY OF OFFSHORE HELICOPTER OPERATIONS AND THE APPLICATION OF FUTURE TECHNOLOGIES TO PREVENT SUCH INCIDENTS.

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Abstract

Companies utilising offshore helicopter operations are continually striving to bring about the necessary improvements in safety, the current accident rate being viewed as unacceptable. Considerable progress has been made on resolving unsatisfactory airworthiness issues since publication of the UK Helicopter Airworthiness Review Panel (HARP) report (Ref. 1) early in the last decade but, until recently, little attention has been paid to Human Factors issues. It is estimated that such issues are significant in over 80% of recent offshore accidents.

With the aim of significantly reducing such accidents in the future Shell Aircraft Limited (SAL) has sponsored a pilot study, the subject of this paper, to identify which technologies have the potential to prevent or circumvent incidents in which human action results in errors prejudicial to the safety of offshore helicopter operations.

The study was fundamentally a two-stage process in which the most critical problems facing offshore helicopter crews were assessed, followed by an appraisal of which technological solutions gave the largest potential improvement to safety. Ease of implementation of each solution was considered such that the practicality of achieving a given safety benefit could be assessed.

This paper concludes with a discussion on the best solutions, with emphasis on those that are not already being studied yet may be available in the short term as a retrofit to current aircraft.

Introduction

Concern at the accident rate involving helicopters in the UK led to the publication of the HARP report (Ref. 1) in 1984 that addressed both airframe and dynamic system reliability. Significant improvements have since been made in these areas but concern is still expressed, amongst those taking advantage of the unique capabilities of helicopters in the offshore market, at the number of recent accidents. Attention is now turning to Human Factors issues, which are currently estimated to be a significant factor in over 80% of offshore helicopter accidents.

Taking an active role in trying to prevent such occurrences happening in the future, Shell Aircraft Limited (SAL) has sponsored two recent studies aimed at reducing the number of incidents in which human action results in errors prejudicial to the safety of offshore helicopter operations. This paper summarises the second of these studies, a pilot study to investigate which technologies have the potential to prevent or circumvent such errors. The study was carried out under the auspices of the Total Air Transport Safety (TATS) working group (a group of UK aviation professionals concerned with improving air safety) by GKN Westland Helicopters Limited (GWHL) and GEC-Marconi Avionics Limited (GMAv). Advisors from the UK Civil Aviation Authority and Bristow Helicopters participated throughout the study.

The key elements of the study, discussed in more detail within the main body of this paper and as summarised in figure 1, are introduced on the following page:-

List of Acronyms

ADS	Automatic Dependent Surveillance
ANC	Active Noise Cancelling
ATC	Air Traffic Control
ECAM	Electronic Centralised Aircraft Monitor
EFIS	Electronic Flight Instrument System
FANS	Future Air Navigation System
FCC	Flight Control Computers
FDR	Flight Data Recorders
FMS	Flight Management System
GMAv	GEC-Marconi Avionics Limited
GPS	Global Positioning System
GWHL	GKN Westland Helicopters Limited
HARP	Helicopter Airworthiness Review Panel
HDD	Head Down Display
HMD	Helmet Mounted Display
HUD	Head Up Display
HUMS	Health and Usage Monitoring System
ICAM	Improved Crew Awareness Methodology
SAL	Shell Aircraft Limited
TATS	Total Air Transport Safety

1) A novel and comprehensive summary of the problems currently facing North Sea helicopter pilots, derived from three separate studies.

2) Reduction of this information to a database of problem statements and the development of a methodology to identify the most critical problems, based on estimates of their hazard level and frequency of occurrence. The resulting list placed the 281 perceived problems, associated with offshore helicopter operations, in an order of decreasing severity.

3) Members of the study team and specialists at both GWHL and GMAv then brainstormed the resulting list of problems to suggest potential solutions. The 189 solutions thus produced were then assessed to consider the potential safety benefit of each solution in terms of the number of problems addressed, severity of these problems and completeness of the solution. At the same time the engineering practicalities of cost, weight, aircraft fit and availability of each solution were appraised.

4) The safety benefit levels and engineering limitations were then given a numeric score such that a ready indication of the ease of implementation of each solution against its potential improvement to safety could be gained.

5) To support the selection of the best solutions an Improved Crew Awareness Methodology (ICAM) was developed. This is a framework for the information flows in a generic helicopter operating environment that allows the mapping of new or enhanced processes and information flows.

6) The top ranked solutions were then selected on the basis of both potential safety contribution and engineering issues. It was found that these solutions readily fell into one of six functional groupings such that their implementation, potential benefits and links to other solutions could be analysed in more detail. In this manner the study produced 24 solutions that are recommended for implementation to improve the safety of offshore helicopter operations by preventing or circumventing human actions which are prejudicial to safety. These were categorised into one of the following three groups:-

1. Solutions that are currently undergoing study.
2. Solutions that are only available in the long term (greater than five years).
3. Solutions that could be developed and trialled in the next five years.

Solutions classed in the first two groups, although having been identified as having safety benefits (and as such recommended for implementation), were not progressed any further in the study, as they are either being considered by other studies or are not able to provide a short term solution.

The solutions in the third group are seen as warranting further consideration, as they have a potential to alleviate current problems, are feasible to implement, or trial, in the near term and are not covered by existing research activities.

7) Finally the research work required and the issues to be resolved in order to bring each of these solutions into service were defined.

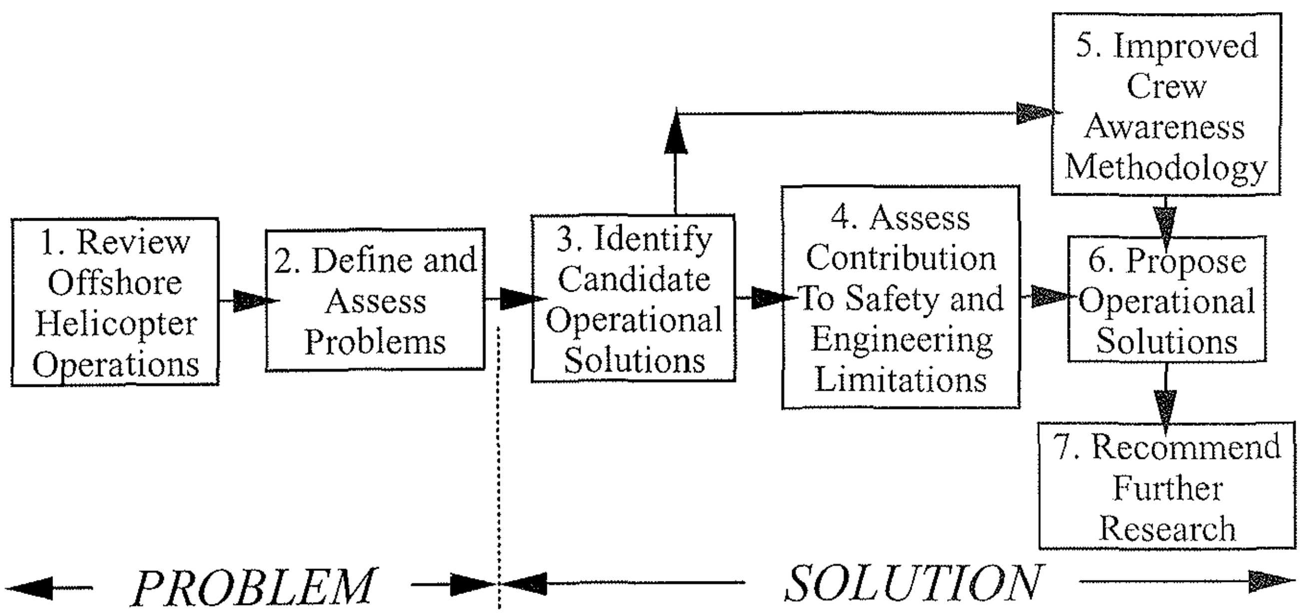

Figure 1. Summary of Study Process.

Appreciation of the Problem

Before assessing how technology may play a role in preventing Human Factor related helicopter accidents it was first necessary to appreciate where human action affects the safety of offshore helicopter operations. To achieve this understanding three separate studies were carried out in parallel.

1) Review of the SAL lead-in study Prior to the study reported in this paper SAL had funded a lead-in investigation (Ref. 2) of the role of human error in helicopter operations, concentrating on Shell's own operations in Brunei. This report was analysed and proved useful, both as a source of information and as a catalyst for in-depth discussion amongst the study team.

The key recommendations extracted from this study and subsequent discussions, placed in no order of preference, are:-

- *Alleviate environmental stress on the crew.*
- *Standardise helideck design and markings.*
- *Improve available torque indications.*
- *Provide assistance for non-handling pilot in visually monitoring approaches.*
- *Improve helicopter handling qualities.*
- *Reduce administrative workload in the cockpit.*
- *Provide automatic interventionist or advisory systems, including fault diagnosis.*
- *Integrate cockpit displays with operational procedures.*
- *Consider aircraft energy management systems.*
- *Improve situational awareness in poor weather and near rigs.*
- *Improve Air Traffic Control (ATC) systems.*
- *Provide autopilot\flight director, if not already fitted.*

2) Review of Related Research/Development Work A wide ranging search was performed to establish what work is, or has been carried out to ameliorate the effects of human error and lack of awareness in flying operations. In addition a number of sources of helicopter accident and incident information were interrogated in order to establish background knowledge on how particular chains of events have led to catastrophe or near catastrophe.

The survey revealed the very broad scope of recent and current research efforts directed towards providing the helicopter pilot with improved systems and displays, so that he may perform his task more effectively and with greater safety. Many of the technologies are being developed specifically for military applications but the benefits that they engender, in terms of improved crew awareness, should make them equally applicable to civil operations in harsh and demanding environments such as the North Sea. The majority of work being carried out centres on three areas; man machine interfaces, sensors and automatic pilot aids.

The first group of technologies aim to provide improved methods for the Pilot to receive information from the aircraft and provide commands to it. In the field of flight information presentation, work is progressing on Head Up (HUD) and Helmet Mounted Displays (HMD) that allow the pilot to devote more time to analysing the external visual environment. Improved display formats are being developed that provide information to the pilot, as required, in a form that is easily assimilated. New methods are also being developed for the pilot to input commands to the aircraft and its systems. These include side arm inceptors to ease the task of controlling the aircraft and direct voice input in order to command system functions.

New sensors are being developed in order to provide improved situational awareness. These include forward looking Infra-Red sensors for poor visibility conditions, Global Positioning Systems (GPS) for navigation, Radar for approaches and miniature microwave devices for proximity detection. Efforts are also underway to fuse the imagery from a number of sensors on either Head Down, Head Up or Helmet Mounted Displays.

The area that appears to be experiencing the greatest activity at present is the field of automatic pilot aids. The simplest form of these will assist the pilot in flying the aircraft and provide indications when any limit has been, or is predicted to be, exceeded. For example Active Control Technology is being researched to assist the pilot in controlling the aircraft, warning systems are being developed to guard against low rotor speed and deviation from the flight path. An interventionist system would take control in such a situation. In some implementations of Carefree Handling Technology, techniques are being developed to protect the aircraft limitations by direct manipulation of the flying controls, whilst providing the pilot with full authority at all other times. A fully automatic system would fly the aircraft with the pilot as the monitor. Increasing levels of sophistication are required with each step in system authority. There is currently considerable activity developing artificial intelligence to aid or supplant the pilot. Knowledge based systems are being developed to recognise pilot intent from a database of pre-defined plans. Action can then be taken if there is a deviation from the plan. Techniques are also being developed to interpret the outputs from a multitude of sensors in order to assess the state of the aircraft, so that corrective actions may be taken if required.

An area which appears not to have been fully addressed is how the emerging sensor and display technology could be integrated, and made accessible to present generation civil helicopters, with the appropriate Human Factors considerations.

3) Analysis of Operational Phases The aim of this study was to identify aspects of the North Sea operational phases that were unsatisfactory to the flight crew. This was achieved by surveying 13 North Sea helicopter pilots from 3 different helicopter operators based in Aberdeen, Scotland.

Due to the limited amount of time and resources of this study, it was impossible to sufficiently detail all operational phases and identify all permutations and combinations of errors that could lead to an accident. It was therefore decided to identify any aspects of the flight that caused this small sample of pilots any potential difficulties. These should then give a good indication of where mistakes can easily be made and, therefore, highlight areas where technology can usefully be applied to avoid them.

It is important to appreciate that the results obtained from the survey are not the definitive view of the potential problems experienced by North Sea pilots. It was not the aim of the survey to produce this. It was, however, intended that the results should be used as a guide to the types of problems that need to be considered when proposing improvements to the helicopter environment.

The survey revealed a large number of problems, encountered by the flight crew interviewed, across all aspects of offshore helicopter operations. The following issues, in no order of preference, were raised by over 75% of the pilots interviewed:-

- *Difficulty in rig identification at a safe range.*
- *Poor rig design, particularly poor positioning of the helideck and the effects of turbulence and hot gas efflux.*
- *Poor identification of the helideck within the rig environment.*
- *Non standard marking of helidecks.*
- *Difficulty of the non-handling pilot in assessing the approach and landing of the handling pilot.*
- *Lack of visual cues at night and in bad weather causing spatial disorientation.*
- *Difficulty in assessing wind speed and direction over the helideck.*
- *Lack of radio altimeter height hold autopilot facility.*
- *High levels of noise and vibration.*
- *Cabin and cockpit heating and ventilation are poor.*
- *Seat adjustment and comfort is poor.*
- *Lack of cockpit layout standardisation across the fleet.*
- *Very complex emergency checklists.*
- *Excessive sector paperwork and paperwork duplication.*
- *Poor communication with the oil companies, including last minute rescheduling of flights.*
- *Poor communication between pilots and passengers.*
- *Poor communication between pilots and deck crew.*
- *Lack of appreciation of helicopter requirements by the deck crew.*
- *Lack of air traffic control coverage.*
- *Inaccuracy and poor availability of rig weather reports.*
- *Poor and out of date rig maps.*

Together these three studies allowed the study team to gain an understanding of the problems inherent in offshore operations, and what is currently being done to address them. Of particular note was the commonality between issues raised in the first and third studies and the large amount of work currently being performed in the military and fixed-wing industries on systems that aim to assist the pilot. What also became apparent was that, although new designs include human factors considerations, relatively little work is being undertaken to address the existing fleets of aircraft, most of which retain systems that fall way behind equivalent fixed-wing standards.

It is believed that these three reports (Vols. 2 to 4 of Ref. 3) form the most comprehensive survey, to date, of human factor related issues in offshore operations. As such they provide a good starting point, that has potential for use beyond just this study, in that the problems that need to be resolved have been identified and relevant research and development work catalogued. In their existing form, however, the reports did not make for easy distillation of the relevant problems, or readily indicate their relative importance. A process was therefore devised to achieve this.

Definition and Assessment of Problem Statements

Each of the above studies were carefully examined and all problems mentioned were extracted as one line statements. This process identified 281 problems which were of varying importance to helicopter safety. These problems were then categorised and evaluated using a numerical data analysis method, developed for this study, to determine which problems were judged to have the greatest impact on safety in the offshore helicopter environment.

Initially the problems were categorised into 6 areas (aircraft design, aircraft type specific, rig design, procedures, air traffic and other) in order to indicate which area within the helicopter operating environment they could be attributed to. They were then assessed in terms of what the outcome would be if the problem occurred, the safety hazard level that the problem posed and the frequency with which the problem was anticipated to occur.

Within this pilot study, only broad categorisation of each problem in each of these areas was carried out.

The safety hazard level was assessed as follows:-

Extremely Hazardous - Results in severe damage to the helicopter, its crew and passengers.

Hazardous - Results in greatly increased chance of an accident.

Contributory - Will contribute towards increasing the hazard level of other problems that might occur during the flight, but on its own does not lead to a safety hazard, e.g. uncomfortable seats.

No Hazard - Problem will not lead to any increase of the safety hazard to the aircraft or its operation.

The frequency of occurrence of each problem was assessed in terms of:-

High - The problem occurs, on average, once a flight in the relevant circumstances, e.g. lack of visual cues at night only occurs on night flights.

Medium - The problem occurs once in up to every 1000 flying hours.

Low - The problem occurs once in up to every 10000 flying hours.

The safety hazard level of the problem, and the frequency with which the problem was judged to occur, were then numerically scored and weighted in order to compare and identify problems that potentially are the greatest risk to helicopter safety. The most serious problems identified, out of the 281 problems considered, are listed below.

The problems judged to be extremely hazardous with a high frequency of occurrence are:-

- *Poor rig design.*
- *Lack of visual cues in bad weather or at night.*
- *Rig design and positioning of obstructions in the way of best climb out path.*
- *Clearance of the rotor blades above the deck with some types of small helicopters.*

The problems judged to be hazardous with a high frequency of occurrence are:-

- *Poor displays.*
- *Poor cockpit layout.*
- *Non standard cockpit layouts and radio fits between the same type of aircraft.*
- *Last minute route changes given to pilots by the oil companies.*
- *Poor communication between pilot/crew and the helicopter landing officer due to noise and poor equipment range.*
- *Inaccurate low airspeed measurement.*
- *Difficulty in assessing the conditions over the helideck and in the lee of it.*
- *Lack of adequate ATC coverage.*
- *Military activity in the North Sea area.*
- *Difficulty in assessing ground speed over the deck, especially in bad weather or at night.*
- *Difficulty in assessing height above the helideck, especially in bad weather or at night.*
- *Difficulty in going from visual cues to instruments immediately after take-off in poor visibility.*
- *Difficulty in range assessment of obstacles in poor visibility or at night.*
- *Poor lighting in the vicinity of the Helideck.*
- *Maps of the oil rigs and boats are not up to date and sometimes wrong.*
- *No ATC radio coverage below 1500ft, even with rig relay stations.*
- *At night, problem identifying helideck due to over illuminated rig, gas flare and dim helideck lighting.*
- *Lack of depth perception at night.*
- *Many navigation beacons on the same frequency.*
- *Incorrect use of weather radars for full instrument approach.*
- *Too much monitoring of visual cues to the detriment of monitoring the instruments.*
- *Difficulty in monitoring the approach and landing due to non-handling pilot's lack of visibility.*
- *Noisy deck environment making it difficult to communicate, especially rotors running reload.*
- *Too many flights that occur between 6:30 to 7:00am and overload the ATC.*
- *Problem with fault detection in bright sunlight.*
- *Difficult to detect small obstructions, such as wires.*

Candidate Operational Solutions

Having identified a comprehensive set of problems concerning offshore helicopter operations the study then turned to deriving solutions that aim to prevent or circumvent such problems in the future.

The first step in this process involved specialists from the study team and their advisors 'brainstorming' the problems, one at a time, to suggest technology based solutions. This resulted in a list of 189 potential or candidate solutions, thereby leading to the question - which are the best?

In order to estimate and assess their benefit to helicopter safety the effect of implementing each solution was considered. An assessment was made, on a problem by problem basis, as to whether:-

- The solution would address all the aspects of that problem, therefore solving it, and so removing all of its detrimental effect on helicopter safety, or
- The solution would address some of the problem aspects and therefore would partially solve the problem, or
- The solution would not address any of the aspects of that problem and so would not improve safety.

A numerical analysis was then devised whereby a score relating to how fully each solution solved a problem, combined with the previously judged severity score of that problem, was summed for all problems. This produced a safety benefit measure, or cost, for each of the 189 solutions such that a list of candidate solutions could be generated. This ranked those solutions that had the greatest potential safety benefit, if implemented in the helicopter environment, down to those that had least impact.

This list, although important as an indication of which solutions would be most beneficial solely in terms of improving helicopter safety, did not take into account the practicality involved in their implementation. Accordingly it was decided to assess, again on a numeric basis, the ease of implementation of each solution such that a trade off between this and safety benefit could be performed for all solutions.

To determine the practicality of implementing the solutions an assessment of engineering issues was carried out. This considered, for each solution, the following parameters:-

- cost per aircraft,
- infrastructure cost,
- mass per aircraft,
- level of aircraft modification required,
- availability.

A total ease of implementation score was then produced considering, for each solution, a summation of each of the above scores with appropriate weighting factors.

Selection of Best Solutions

Having assessed and numerically scored the safety benefit and ease of implementation of each of the 189 solutions a scattergram (Figure 2 below) could be constructed to visualise the relative merits of the solutions according to normalised values. This safety/ease of implementation plot illustrates that the most worthwhile solutions will be more difficult to engineer, whilst the solutions that can be implemented more readily have relatively little safety value.

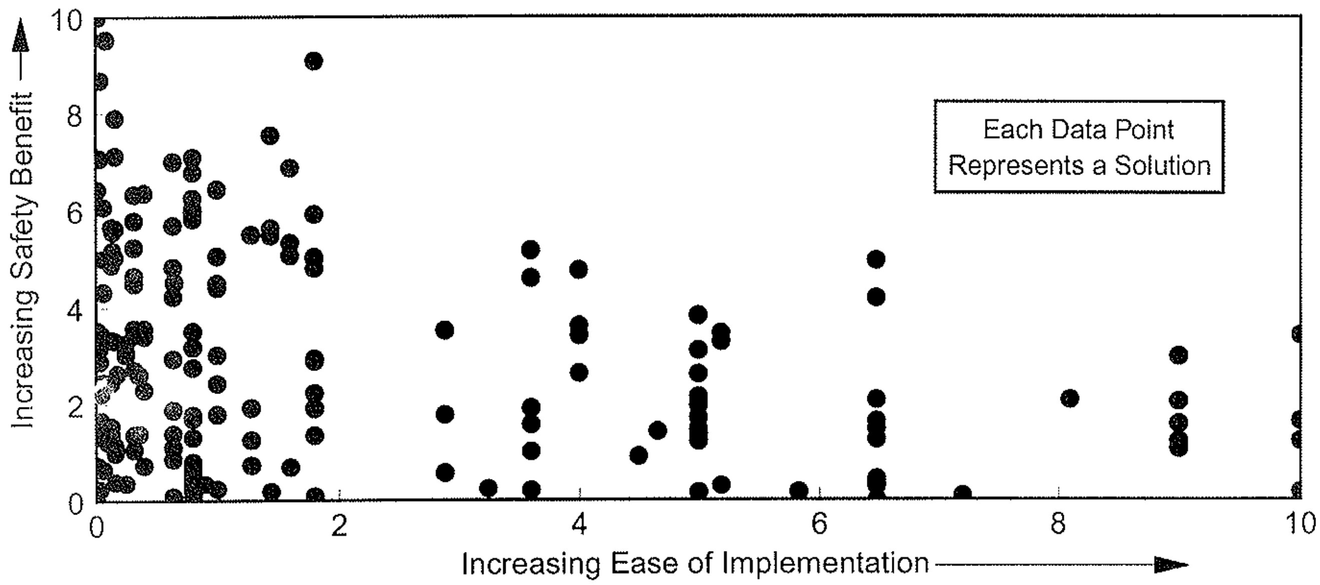

Figure 2 Comparison of the safety benefit and ease of implementation for all solutions

In order to choose the best solutions for further analysis a criterion for selecting the best solutions was required. After careful deliberation it was decided to select solutions from the area above a line drawn through the data, this line having a gradient such that safety benefit was given twice the significance of ease of implementation. The positioning of the line could be adjusted to ensure the required number of solutions were captured.

The top 70 solutions satisfying this criterion were listed in descending order for further consideration. Of these it was proposed to select the first 40 practical solutions (this being the maximum amount considered addressable within the pilot study). Progressing down the list, those solutions that were considered impractical were dismissed from further study. It should be noted, however, that developments in technology may affect the practicality of these solutions in the future.

Five further solutions were scored outside of the top 40 but their merits were deemed subjectively to be worthy of further study. It was then seen that each of these 45 solutions fell into one of six functional groups (approach aids, flight management, aircraft system awareness, and aircraft, cockpit and rig design) facilitating further analysis.

To consider the functionality of each solution in more detail and, in particular, possible integration of solution functionality, a means of describing how each solution works and interfaces with the flight crew, within the helicopter operating environment, was required.

Improved Crew Awareness Methodology

To allow the mapping of new or enhanced processes and information flows, identified as being required for improved crew awareness, a framework for the information flows in a generic helicopter operating environment was required. Due to the scope and complex nature of the offshore environment it was decided that an explicit and formal method of modelling and detailing the system solutions should be adopted. This would then enable accurate and rigorous modelling resulting in a complete and precise representation of the helicopter's operating environment.

The methodology developed is referred to as the Improved Crew Awareness Methodology (ICAM) and was used in support of the selection of the best solutions by addressing their functionality within a single coherent framework representing the helicopter operating environment.

The techniques of "Structured Analysis" are commonly utilised in the discipline of systems engineering, enabling the definition of complex systems in a straightforward diagrammatical manner. Structured analysis is a process modelling technique that is used for describing the functional characteristics of a system. It involves modelling the flow and transformation of data through the processes of a system, and the decomposition of these processes. It is a hierarchical method of breaking up a whole system into smaller, understandable parts, and describing these smaller parts in greater detail.

The technique uses a graphical language to diagram information as it flows and is transformed within a system. The language uses a simple symbol set and provides a powerful, straightforward concept to represent the functional view of a system.

The method used for the ICAM diagram was adapted from the Yourdon\De Marco Data Flow process modelling methodology. This methodology was developed from a paper and pencil technique that uses circles as process symbols and arrows as dataflows. While the basic methodology is common, some of the symbology of the original method has been adapted for this study in order to allow the representation of new and improved dataflows.

The top level diagram of the ICAM describes the overall context, in terms of processes and information flows, of North Sea Helicopter operations. This diagram is broken down into 3 sub-diagrams to provide greater detail of the data flows relating to the *airfield*, the *aircraft* and the *rig*. These decomposed diagrams were considered as the minimum required in order to illustrate the data flows associated with the future technology solutions. As an example Figure 3 shows a section of the rig diagram. Each diagram is accompanied by a data dictionary, which defines the contents of each data flow shown on the diagram. The data dictionaries define the data flows in terms of the data structures from which they are made up and in turn the data elements which make up each data structure. This allows the user to trace data from process to process and diagram to diagram.

By combining the graphical and textual aspects of the ICAM the user can quickly assimilate the information flows. For example the rig_voice_to_aircraft data structure shown in figure 3 is made up of the following data elements: rig weather data, rig permission to land, return passenger data and return freight data.

All top ranked solutions in this study were analysed in the ICAM framework to assess their functionality, in terms of new or enhanced processes and information flows, within the offshore helicopter operating environment. It is proposed that this methodology has uses beyond this study and has potential for application to safety issues in the design and analysis of future systems, and in accident investigation.

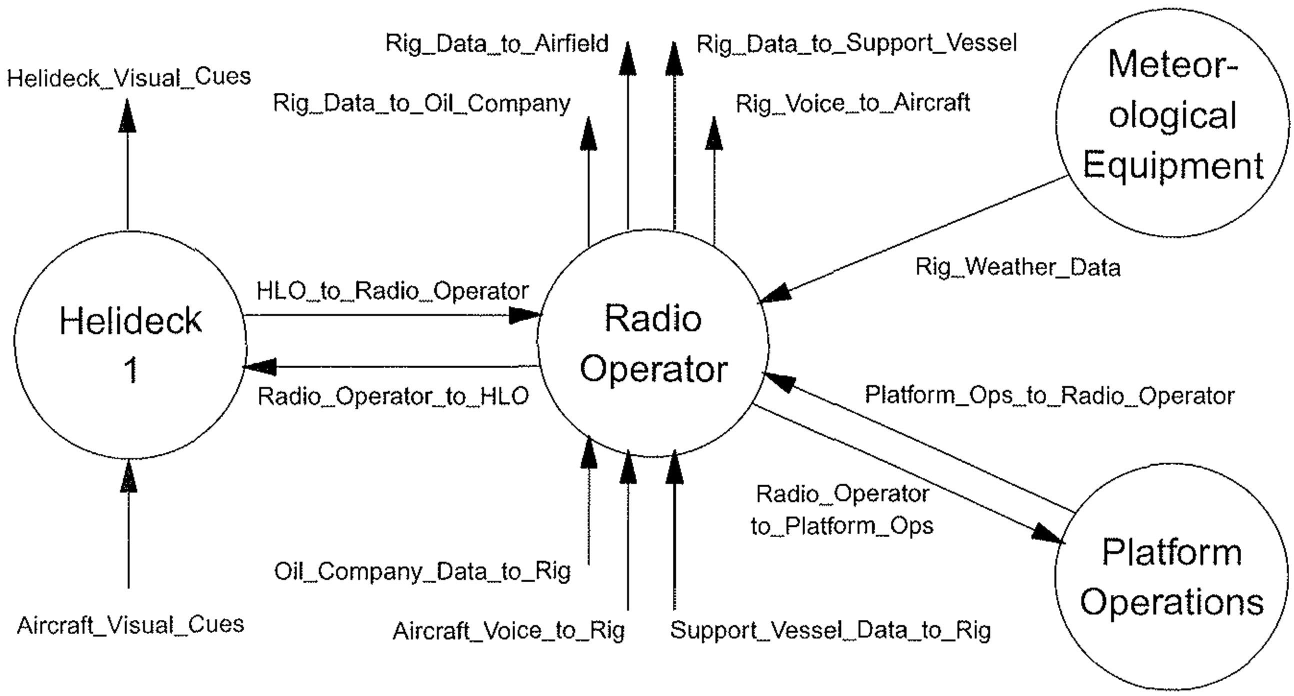

Figure 3. Section of the rig ICAM diagram

Recommended Solutions

The detailed assessment of the top 45 solutions resulted in the recommendation of the 24 solutions listed below. These were categorised into one of the following three groups:-

1. Solutions that are currently undergoing study (functional group shown in brackets):-

- *GPS (Approach Aid)*
- *Automatic Flight Path Control (Approach Aid)*
- *Aircraft Automatically Reporting Back to ATC (Flight Management)*
- *Improved Visibility of the External Environment (Aircraft Design)*
- *Improved Aircraft Performance (Aircraft Design)*
- *Improved Autopilots (Aircraft Design)*
- *Active Noise Cancelling Headsets (Cockpit Design)*
- *Improved Cockpit Lighting (Cockpit Design)*
- *Automated Weather System (Rig Design)*
- *Helideck Textural Cues (Rig Design)*
- *Standard Helideck Lighting (Rig Design)*

2. Solutions that are only available in the long term (greater than five years):-

- *Carefree Handling (Aircraft Design)*

3. Solutions that could be developed and trialled, as a retrofit to existing aircraft, in the next five years:-

- *Downward Looking Camera with Information Overlaid (Approach Aid)*
- *Obstacle Detector (Approach Aid)*
- *Electronic Schematic of Rig (Approach Aid)*
- *Simple HUD or HMD (Approach Aid)*
- *Mapping of Air Profile Around Helideck, Rig and Helicopter (Approach Aid)*
- *Low Airspeed / Groundspeed Measurement (Flight Management)*
- *Flight Management Systems (Flight Management)*
- *Self Monitoring Process (Flight Management)*
- *Improved Head Down Displays (Aircraft System Awareness)*
- *Helicopter Engine and Rotor Management System Aircraft System Awareness)*
- *Cockpit Fault Warning System (Cockpit Design)*

There was one further, and very important, solution that covered all functional groups and timescales:-

- *The application of human factors consideration to all design activities*

Each of these 24 solutions have been identified as providing a major safety benefit and are therefore recommended by the pilot study for implementation.

The eleven solutions in the third group were considered further by the study team, as they each have the potential to alleviate current problems, are feasible to implement, or trial, as a retrofit to existing aircraft in the near term and are not covered by existing research activities. Ways and means of implementing each solution were discussed and, where possible, further development and/or trials activities necessary to lead to their implementation outlined.

The following sections discuss each of these solutions separately (grouped according to function), paying particular attention to the description of the technology and the work required to bring about a working solution.

APPROACH AIDS

Downward Looking Camera with Information Overlaid In order to allow the non handling pilot to assess the handling pilot's approach and landing on a helideck a downward looking camera, mounted underneath the aircraft, could be used. This camera, which may be gimballed or fixed at a particular angle, would allow the non handling pilot to assess the landing site when the orientation of the helicopter is such that it obscures his view. In order that the non handling pilot can still monitor the instruments, as he is required to do, relevant information could be overlaid on the display. This would allow the non handling pilot to monitor the approach and the instruments without moving his head, maintaining his situational awareness, with no loss of capability to monitor the aircraft systems.

Cameras have been fitted to the underneath of helicopters for surveillance and considerable experience has been gained in the details of mounting them. However, such technology has not been successfully exploited in this application.

Obstacle Detector Laser obstacle detectors can give range measurement directly and are accurate enough for obstacle detection at the short ranges associated with helideck landings and take-offs. Because the transmitters can be of relatively low power and are small, they can be distributed, so as to protect especially vulnerable parts of the helicopter, such as the tail rotor.

The concept of the obstacle detector can be extended, by modifying the wavelength and required range of the laser, so that it can be used to detect larger obstacles such as ships over a longer range. This information could then be displayed as an overlay to the existing weather radar display.

Trials of both of these aspects are currently being carried out, where this technology has already been successfully applied to maintaining vehicle separation between cars travelling in the same traffic lane.

Electronic Schematic of Rig A computer generated schematic of the rig displayed on a Head Down Display (HDD) would allow the pilot to see, at a glance, the layout of the destination rig. This would enable him to plan his approach even if the actual rig were previously unfamiliar, the visibility was poor or it was at night. This would help to reduce the chances of the pilot becoming disorientated with respect to the rig and would also allow the pilot to verify that he was approaching the correct rig by comparing pertinent features.

The schematic of the rig display could then be enhanced by, for example, overlaying obstacles, highlighting the helideck, showing wind direction, indicating recommended approach angle, speeds and particular turbulence problems. The technology for producing the display is available today, although a product has not yet been developed.

Simple HUD or HMD A simple Head-Up Display (HUD), or ideally Helmet Mounted Display (HMD), would allow the crew to monitor critical aircraft parameters without ignoring the external visual cues. The flight crew would be able to spend more time with their eyes out of the cockpit and as a result, will have better situational awareness, especially at night or in conditions of poor visibility.

The technology to build HUDs and HMDs exists, although the full systems are complex and expensive. A minimum HMD system could be provided without attitude information, therefore removing the need for head tracking equipment. Work has been carried out on a light weight cheap HMD which could be relatively simply trialled and tested in the North Sea helicopter environment.

Mapping of Air Profile Around Helideck, Rig and Helicopter Accurate control of the helicopter's position and flight path can be adversely affected by turbulence, resulting from interaction between the free stream and the rig. Mapping of the airflow can reveal potential problems areas for landing and take-off and help in estimating optimum paths for approach and departure.

Mapping the airflow around a complex structure such as an oil rig is a demanding task. There are difficulties in placing the sensors used to measure the profile so that they obtain accurate wind speed measurement. Integration of individual windspeed measurements to give a profile over the rig will require accurate knowledge of the rig structure and location of the sensors. The presentation of this information to the pilot in a meaningful manner, will require development of complex algorithms due to the three dimensional nature of the flow field, and will require the use of some form of data link to uplink the information to the helicopter for its graphical display to the pilot.

FLIGHT MANAGEMENT

Low Airspeed / Groundspeed Measurement There are two aspects to this solution; the need to measure low airspeed and the need to relate airspeed to groundspeed during near ground manoeuvring and hovering.

The need to measure low airspeed is brought about by the nature of the helicopter power requirements. They are such that small variations in airspeeds at the low end of the range i.e. close to the hover, can have large effects on the power required to maintain level flight. The accuracy of low airspeed measurement on current generation aircraft is regarded as inadequate which can lead to problems in low speed manoeuvres such as take-off, landing and hovering. Ideally these should be performed nose in to wind in order to provide the greatest power margin. However, with the poor low airspeed measurement this is difficult to achieve, consequently reducing the safety margin and increasing crew workload.

Accurate knowledge of groundspeed or, more precisely, the ground velocity vector, suitably displayed, can prevent drifting into dangerous areas and permit rapid response to turbulence over the helideck. This is important when in the hover, to ensure that the helicopter is remaining stationary with respect to the ground.

Currently, there is no off the shelf, cost effective solution and the implementation choice should be made as part of an integrated solution.

Flight Management Systems (FMS) Most current helicopter FMS are limited and have a poor pilot interface. They could be enhanced by implementing a more friendly user-interface and more intelligent algorithms for parameters such as fuel monitoring. This would then allow the FMS to monitor the aircraft's progress along the flight path more precisely, giving it the ability to accurately direct the helicopter along the flight path, whilst constantly monitoring the fuel and load state of the aircraft. As a result, this would improve helicopter operational efficiency, and reduce the pilot's workload.

As part of improving the FMS, the helicopter will require better navigation capability and it is recommended that a form of electronic map display is made available. Electronic maps will enable the pilot to assess his progress along the flight plan, and maintain good knowledge of his position, particularly with respect to the flight path, at all times, thus improving his situational awareness. Also, by displaying the rig positions on the map, possibly with textual information to identify them, the likelihood of the helicopter landing on the wrong rig should be significantly reduced.

Self Monitoring Process The current monitoring systems within helicopters are basic and apply no intelligence when signalling to the pilot that some parameters are not within the expected tolerance. A central monitoring system could be added to the aircraft to monitor the aircraft systems and deduce from certain combinations of factors what the fault is. This information could then be displayed to the pilot, allowing him to readily assimilate the problem without having to diagnose it himself. Thus, this could avoid pilot distraction in problem diagnosis and reduce pilot reaction time to the situation caused by the fault.

The central monitoring system could be extended to include monitoring the pilot's actions. This could be achieved by an intelligent system where the monitor would have knowledge of the allowable flight envelope, procedural requirements and all the aircraft systems. The central monitoring system could then be in a position to assess the pilot's actions, and give him timely and clear warnings when he is doing anything that does not conform with the known procedures or helicopter capabilities.

AIRCRAFT SYSTEM AWARENESS

Improved Head Down Displays Current generation North Sea Helicopters are mainly equipped with electro-mechanical head down displays providing dedicated display surfaces, usually for individual parameters, with little integration of information. This leads to a cluttered cockpit arrangement with many dials and gauges, often with ad hoc additions, from which the pilot must distil the information he requires. This problem is compounded by lack of standardisation across a fleet.

There are two strands to the future research proposed to address this problem. Firstly to examine what is wrong generally with displays that has caused improved displays to be cited as a main solution. Full ergonomic assessments of the existing fleets could lead to specification of minimum standards of equipment fit, displays, and cockpit layout for given aircraft types. Secondly research is needed to examine the feasibility of providing retrofittable display surfaces and the specific display requirements of each of the solutions proposed in this pilot study.

Helicopter Engine and Rotor Management Systems Predicting a helicopter's performance depends on many factors, about which there is not always sufficiently accurate knowledge. Knowledge of the actual performance of the engine and transmission system (as compared with the brochure values), the lift available out of ground effect and the actual weight (as against the estimated figure) are often critical in situations where safety is in question. An energy management system can assess the actual lift margins under the prevailing conditions and enable them to be predicted at destination, thus enhancing the safety of the operation. By periodic calibration, e.g. measuring the lift margin out of ground effect, it is possible to calibrate the condition of the complete system for maintenance purposes.

Such a system could be used in conjunction with an improved power margin display and audio warning system to provide advisory information to the pilot concerning available aircraft power at all stages of the flight. i.e. dynamically changing the available power limits. This may provide increased flexibility and manoeuvrability to the aircraft under certain conditions providing increased safety margin. It will also warn the pilot of conditions which may limit aircraft performance, thereby ensuring that the pilot doesn't enter a flight regime which will exceed the available power.

Such a system is viewed as an extension of the existing Health and Usage Monitoring System (HUMS) and Flight Data Recorders (FDR) with a higher data rate and the additional capability of in flight mass and centre of gravity calculation. It is also seen as part of the evolutionary process that leads to an intelligent flight monitor or pilot's associate.

COCKPIT DESIGN

Cockpit Fault Warning System Automated fault diagnosis systems could help to reduce crew workload if correctly implemented and made sufficiently reliable. To provide this functionality effectively, EFIS technology will be a requirement.

A cockpit warning system which is able to diagnose the nature of aircraft system faults (including false alarms) and present a prioritised list of suggested remedial actions to the crew in an unambiguous form would, potentially, be a safety improving system. Systems of this nature are emerging in the fixed wing world, e.g. the ECAM (Electronic Centralised Aircraft Monitor) system on Airbus A320-340 variants and should be adapted for application in rotary wing aircraft.

Conclusions

This pilot study allowed the study team and their advisors to focus their broad industrial experience and skills on the subject of offshore helicopter safety. Their co-operation made it possible for the pilot study to:-

- *document the current offshore helicopter safety situation and relevant research,*
- *collate and classify the helicopter safety problems identified,*
- *identify candidate solutions that prevent or circumvent these problems,*
- *produce new methods for analysing candidate solutions,*
- *list the solutions according to their safety benefit and ease of implementation,*

The pilot study stimulated co-operation between many organisations concerned about safety, raised awareness of the key issues and supported the rationale for existing work on safety improvement.

The major outcome of the pilot study was the identification of 11 practical technological solutions that improve the safety of offshore helicopter operations. These solutions are all achievable as retrofits within five years and are not currently being studied. Recommendations for research and trials leading to the implementation of these solutions were made.

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