Technology- Help or Hindrance?
Ensuring the Successful Introduction of New Crewstation Technologies into Rotorcraft

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Abstract

The introduction of new crew interface technologies into civil and military helicopter platforms has not always been a total success. While the equipment may have been effective in its conceived role it has sometimes introduced unforeseen human factors issues. Examples include the introduction of GPS navigation systems into small private helicopters and the use of Night Vision Goggles by both civil and military operators. An overview of this past experience is presented, together with some general thoughts on problems of technology insertion for crew interfaces, and why human interaction may not be as predicted.

A number of new technologies are now reaching maturity and have the potential to extend the operational capability and safety of rotorcraft. These include the next generation of vision systems, advanced mission management systems, and non-visual sensory input/output systems such as Direct Voice Input, 3-D Audio and haptic (physical sensory) systems. The paper reviews the status and technology readiness levels of these systems and considers how each may contribute to enhancing mission capabilities and reducing or redistributing pilot workload.

The final section of the paper discusses the processes for human systems integration (HSI) by which such new technologies may be integrated and implemented safely and effectively on to future helicopters. In particular the importance of involving the operators / potential users and the human factors specialists alongside the systems engineers at all stages of the process is identified.

This paper stems from the proceedings of a conference held at the Royal Aeronautical Society in February 2004.

Introduction

The tasks facing the aircrew of military helicopters have become increasingly difficult and complex with time. This can be attributed to a number of causes including: increasing sophistication and complexity of enemy threat systems; increasing diversity of weapon systems; increasing complexity and functionality of avionic equipment installations within given mass and volume constraints; the demand for increased mission capability to counter threats and meet operational demands; and achievement of these enhancements whilst pursuing the quest for increased safety. Thus the modern helicopter pilot is given a substantial array of controls accessible on his manual inceptors (cyclic and collective sticks), has available enormous amounts of data, and is required to fly in increasingly adverse environments in terms of visibility, altitude, terrain and threats.

The natural response to this continuing demand for enhanced operational performance is to turn to new technologies for solutions. A good example has been the introduction of night vision goggles for helicopter operations in poor light conditions. Sometimes the introduction of new technology is driven as much by the availability of that technology as much as by the operational demands; an example in the civil sector is the introduction of GPS into small private helicopters.

Unfortunately, experience has shown that the introduction of such technologies has not always been successful in achieving the intended enhancement in performance or safety. The response of the human operator is not easily predictable and may include some unexpected and adverse behavioural aspects. Similar unexpected results have been seen in the world of motoring where numerous studies by insurance companies have failed to identify any benefit to accident rates resulting from the introduction of anti-lock braking systems. It appears that drivers are changing their habits and effectively driving to a constant level of perceived risk (Ref 1). It is also now acknowledged that the introduction of car seat belts has resulted in no measurable reduction in the overall rate of road deaths, albeit there may have been a shift in the distribution away from car occupants towards third parties such as pedestrians and cyclists (Ref 2).

Thus, while equipment may have been effective in their conceived roles and modes of operation, the reality is often more complex, with the beneficial effects being degraded or overcome by unforeseen human factors issues. In the case of the introduction of GPS navigation systems in small private helicopters, pilots have assigned too much confidence to the system and have ventured into inappropriate conditions, in some cases with fatal results. Similarly, the availability of Night Vision Goggles for both civil and military operation carries the risk of over-reliance by pilots, combined with a lack of awareness of the limitations of the systems, which may result in some enhancement of operational capability but at the expense of reduced safety.

New aircraft programmes are becoming rare. Generally, there is a trend towards more evolutionary acquisition, spiral development and technology insertion programmes. This trend presents new challenges for human systems integration and for assessing and mitigating human factors risks.

Faced with this somewhat adverse experience and realising that a number of new, attractive technologies with potential application at the man-machine interface are maturing and will soon be available to designers and operators, a one-day conference was held at the Royal Aeronautical Society in London in February 2004 (Ref 3). This brought together all relevant sectors of the rotorcraft community – researchers, technologists, test and evaluation specialists, human factors engineers and psychologists, regulators, and civil and military operators – with the aim of sharing understanding of the issues and debating what steps might be taken to ensure more predictable and effective application of new technologies in the future.

This paper draws on the presentations made at the conference by an array of specialists and attempts to draw conclusions and recommendations from the lively discussion period. The authors would like to acknowledge the contribution made to the day's proceedings by all the speakers, panel members and audience. However they emphasise that the views expressed are their own. The programme for the conference is at Annex A.

Past Experience

As mentioned above, two examples of unanticipated human response to new technologies have been highlighted.

Night Vision Goggles.

UK first introduced binocular NVGs for military helicopter operations in the early 80s, but rapidly realised that they were not a panacea for night flying; they did not turn night into day. Issues encountered and dealt with over many years of subsequent usage include the following:

- The use of NVGs could greatly increase aircraft capability but the piloting task was much more complex. Factors included the restricted field of view, lack of peripheral vision and optical flow, the monochrome picture, and difficulty in interpreting scenes devoid of texture (stemming from the lower image resolution).
- The need for compatibility of cockpit lighting. This was initially addressed by use of NVG-compatible floodlighting and subsequently with appropriate backlighting of the cockpit instruments.
- Formal training in the use of NVGs is essential and must be updated regularly as the skills are highly perishable.

The overall conclusion has been that while the evolving technology for NVG operations has increased operational capability, the piloting task is not necessarily made any easier. The skill is very perishable, implying the need for a greater amount of continuation training. Also, there is a need for a better standard of pilot students.

An important issue to be considered is the additional costs incurred in establishing and maintaining the operational capability, arising from:

- Cost of provision of the technology
- Cost of integration into the cockpit
- Cost of significant additional training
- Cost of continuation training to mitigate skill fade with time
- Costs of recruiting and screening for higher calibre students initially.

Other considerations learned by experience are the danger of over-reliance on the technology, lack of understanding of the limitations of the technology, the additional scope for operator mistakes in complex systems, and the overall feeling of invincibility conferred by the technology which can lead to over-confidence.

GPS Navigation Systems

GPS-based navigation systems have become available to the civil helicopter community and are being used increasingly by small private operators. However the UK CAA is becoming concerned at the number of accidents, some fatal, which may be attributable to the inappropriate use of the systems.

In principle, GPS is a very attractive system with numerous advantages:

- Avoidance of getting lost
- Assistance in avoidance of controlled airspace
- Reduced time devoted to head-down navigation tasks and hence improved lookout time
- Improved capability to operate in poor weather
- Enabling of precision approaches
- Provision of a substantial database - way points, etc

Thus it may appear to be a perfect, highly accurate, navigation aid. However, the practical reality has some adverse points:

- The system may induce pilots to fly in poor conditions "because they can".
- When operational safety is reliant on the GPS, there is a consequential reliance on the availability and integrity of the system.
- The availability of GPS data may have an undue influence over pilot behaviour; it may cause loss of basic airmanship skills, for instance in flying with reduced margins for error.
- It may seduce the pilot into using it for inappropriate purposes. For instance it may not be certificated for sole use or for IMC/IFR operations.

The CAA is currently considering these issues with a view to generating operational recommendations and/or regulations.

Summary of Experience

From these and other experience, it is clear that the introduction of new technologies on to civil and military helicopter platforms has not always been straightforward or a total success. While the equipment may have been effective in its conceived role, it has sometimes introduced unforeseen human factors issues. The existence of standards such as NATO STANAG 3994 "Application of Human Engineering to Advanced Aircrew Systems" and JAR 25 does not guarantee success. However a lesson learned from past experience is that the parallel involvement of engineers, human factors specialists and operators at all stages is essential. The importance of an integrated approach increases with moves towards more evolutionary acquisition, spiral development and technology insertion programmes.

One problem has been the need for definition of the scope of human factors integration issues. The recent publication of the Human Systems Model (UMMi) by ISO provides a significant milestone in international agreement on the ergonomics of human-system interaction and usability process assurance - ISO/PAS 18152:2003 (Ref 4).

As discussed in the next section, a substantial number of new technologies are maturing which will be available to the helicopter community. The challenge is to ensure that their introduction and use in service is successful and contributes to both capability and safety.

Advances in technology

The systems discussed in this section are a selection of the more significant crewstation technologies being developed with the aim of enhancing the operational performance and safety of helicopters in increasingly demanding operational environments. A major aim for both the civil and military communities is to establish a truly all-weather helicopter capability. This review is not claimed to be comprehensive but it demonstrates the impressive range of options that is, or soon will be, available. Each will present new challenges in introducing it successfully into the cockpit environment.

Vision Systems – NVGs and beyond

The helicopter pilot is faced with a complex task involving flight control, guidance of the aircraft in relation to the features of the outside world, navigation, and mission task. In all these he is dependent to some extent on information extracted from the visual scene. The aim of the vision systems is to minimise the loss of mission effectiveness and safety in degraded visual conditions. Systems can range from stand-alone NVGs to complex integrated vision systems comprising a complementary set of sensors to gather information, image processing to extract and highlight information, and display technology to enable the intuitive presentation of the information.

A first step forward in advanced vision system technology has come with the development of panoramic night vision goggles, extending the lateral field of view from 40° for conventional NVGs to around 95° and hence giving greater situational awareness. Flight trials in UK, US and Canada have already demonstrated their effectiveness in improving situational awareness and reducing pilot workload in a range of piloting tasks. Beyond this, a number of active and passive systems are available, including electro-optical sensors, image intensifiers, thermal imagers, LADAR, and active or passive millimetric wave radars; these complementary systems have the potential to provide a capability to penetrate all weathers. Fusion of the images from a mix of these sensors can create images far better than those from any individual sensor. Images may also be combined with synthetic imagery from a database. The use of sensors mounted on the pilot's helmet together with display of processed imagery on the visor means that head tracking becomes an essential component of the overall system. Systems with image fusion and with conformal symbology overlaid and registered on the outside scene have already been demonstrated in flight trials.

A 'sensor – processing – display – human' systems engineering approach is essential if the overall system is to be successful in meeting the objective of providing adequate situational awareness in all atmospheric environments and light levels. In doing this, there is a need to ensure the correct balance of information, utility and ease of use, without over-burdening the operator with excessive visual workload.

Mission Management Systems

This broad heading covers systems that support the human decision making process for pilotage and mission objectives. The system should provide the aircrew with real-time automated support for functions such as in-mission re-routing and re-planning, autopilotage, tactical picture maintenance and decision making, and management of platform sub-systems. Fundamental to system operation are the gathering and fusion of data, particularly from sensors, and the interpretation and fusion of this and other data into information to support the crew in mission context awareness and decision making.

The data fusion can include the fusion of images from sensors as discussed above, augmented by the introduction of other overlays such as threat data. It can reduce display clutter and hence reduce workload. Since the data is taken from a number of sources, a degree of redundancy may be introduced. By use of the best capabilities of each sensor, accuracy should be improved and uncertainties reduced, for instance in classifying or identifying objects. At the next level up, information fusion should draw on all available sources of data, to construct an overall tactical picture in the form needed for decision aiding.

From a human factors point of view, the system must provide the crew with the right information to support the mission task and objectives, in the right form and at the right time. Difficult issues to be addressed include the extent to which the system is able to make decisions itself, the safety criticality of the various elements of the system, the degree of intelligence incorporated and the need for crew supervision of automated MMS. The challenge is to design advanced automated MMS with easily maintained, and correct, levels of crew involvement in critical decisions. If correctly conceived, the MMS has the potential to improve situational awareness and allow crews to undertake more complex tasks in more stressing environments.

Audio Systems

Two audio technologies have been developed to a state of maturity ready for introduction into helicopters, namely Direct Voice Input (DVI) and 3-D Audio (Ref 5). These are supported by well-established Active Noise Reduction (ANR) technology.

Direct control of cockpit systems using speech recognition technology can reduce the need for the crew member to take hands off his primary manual controls or look down into the cockpit, thereby maximising concentration on the flying task and keeping “eyes out”. DVI is not intended to replace manual inputs but to complement them. This is particularly useful when other mission demands mean that the pilot cannot easily release the flying controls or look down, thereby enhancing situational awareness and hence mission effectiveness and flight safety. Amongst the potential applications are the switching of radio channels (already demonstrated in service on a UK police helicopter and in UK trials on a military helicopter) and the operation of multi-function displays, particularly those involving complex data hierarchies with several layers of contents pages.

The speech recogniser function available for DVI systems has evolved to be fully speaker-independent. It is usable by any speaker, with no training overhead and can adapt to changes in the speaker’s voice, for instance as a result of stress. The use of noise cancelling microphones has been shown to be highly effective in conjunction with DVI in helicopter cockpits. Trials in a fully representative helicopter cockpit environment have shown that the DVI system can give a higher level of accuracy than manual input.

3-D audio systems enable the spatial location of sound; the audio seems as if it comes from spatially separate locations outside the pilot’s helmet. This means that the audio signals are no longer acoustically mixed inside the pilot’s head. An initial application envisaged is for spatial resolution of communications channels, thereby improving intelligibility. If combined with head tracking the audio can be aircraft-referenced, and if aircraft orientation inputs are applied, the audio can be world referenced, opening the possibility of other useful functions. Tests have also shown benefits in reduced fatigue and reduced risk of hearing damage.

Haptic Systems

The four fundamental sensory cues relied on during flight are visual (sight), audition (hearing), vestibular (balance) and haptic (touch). Given the tendency to overload the pilot’s visual and, potentially, audio senses, attention has turned to conveying information via other senses, in particular the haptic. This has a number of sub-senses including tactile, force / motion / position, temperature and pain.

Some haptic systems are already familiar. Aside from the obvious devices such as buttons and switches, we already have systems with haptic feedback, such as the stick-shaker stall warning used in fixed wing aircraft and the active force feedback sidestick controller developed for rotorcraft use. A more recent development has been the Tactile Situation Awareness System (TSAS) from the US NAMRL; this incorporates an array of vibratory sensors distributed over the torso, controlled energisation of which has been shown to avoid spatial disorientation and motion sickness. It is envisaged that such a system might be extended to provide other mission-related stimuli to the crew member, for instance to notify of threats or targets.

Those involved in research in haptic systems believe they have great potential to provide a viable alternative to conventional visual and audio systems in management of overall workload within the cockpit. However, the human capacity for haptic inputs is not well understood, nor is the interaction of haptics with other human sensors. In some situations, haptics will dominate over vision or audition, but in others the reverse is true.

Advanced Flight Control

Clearly, a major task for the pilot is flying the aircraft. As mission demands have become more stringent, for instance in low level, terrain following flight in poor visibility and operations on to ships in severe atmospheric and sea conditions, the basic flying task has become more difficult. Major advances have been made in development of enhanced flight control systems (FCS) to assist the pilot.

The vast majority of current helicopters have mechanical systems linking the pilot’s hands to the rotor control actuators. However digital fly-by-wire systems are now being certified for rotorcraft, for instance in the NH90 and BA 609. Benefits can include reduced system weight, improved reliability and reduced maintenance. The use of a digital FCS is also the foundation for enhancing the functioning of the Automatic Flight Control System (AFCS), with the possibility of including enhanced handling qualities, particularly in the more demanding piloting situations. Carefree handling becomes a possibility, for instance in protecting the aircraft from inadvertent over-torques. In the longer term, the FCS can become a core element within an integrated Vehicle Management System, with interaction with other aircraft systems such as the engine control system, displays, weapon systems, etc. Each advance in FCS technology has the potential to reduce piloting workload and hence enhance pilot effectiveness and overall mission effectiveness.

Technology Integration

In the foregoing sections, we have seen that the introduction of new crewstation technologies has not always been straightforward or entirely successful, and that we are now faced with an array of new technologies which are reaching maturity and have the potential to bring significant operational and safety benefits. Some of these technologies are extensions of existing systems, but some are novel and have the potential to change the way we do things. In either case, the challenge is to establish a process by which the use of novel technologies within helicopters may be specified, certificated, introduced to service and regulated so as to ensure that they help rather than hinder the crew in achieving enhanced operational effectiveness and safety.

In the following sections, some thoughts are offered on the technical considerations (in particular the human factors issues) and the activities which can contribute to success.

Exploiting Research

The first point at which new technology can stray from an ideal path to successful use is in the transition from a research concept to a mature technology ready for adoption into a specific application. A Technology Demonstration Programme can provide this bridge. The TDP should still address generic technology, but it should be done in as realistic environment as possible, including the appropriate stressing environment for the human operator and the physical environment of the helicopter. The value of TDPs in identifying development and operational issues at an early stage cannot be over-emphasised.

Specification

An essential step in introducing a new crewstation technology into a particular application is the creation of an appropriate specification. In the first instance the user specification should be defined in terms of the required functionality, at an overall system level, and this can then be developed to a more detailed engineering level. The specification should set the introduction of new technology into the overall operational context. In practice, the specification for the new system will be bounded and is unlikely to reflect the totality of the installation and operational environment. However it is essential that these broad considerations be addressed as part of the design, development and T&E processes. The specification should call up the relevant standards and guidelines, including those relating to human factors.

Given the difficulty of specifying the system in the totality of its operational environment, including the stressing environment for the aircrew, there may be a need to accept a risk sharing approach between the system designer and the user.

Although not an immediate human factors issue, it is important that in the specification and the subsequent engineering design and development of new systems, account should be taken of the need for longer term sustainment of the system and minimisation of the dangers of obsolescence. It is no use having a highly effective system only to find after a few years that it is unsupportable.

Design, Development, Test & Evaluation (T&E) and Certification

The introduction of new technology must be addressed in the context of the overall helicopter system, not as an isolated system. Its interactions with other aircraft systems must be understood, not only as an engineering interaction but also at a human factors level. The use of modelling and simulation from the outset can assist in early identification of adverse human responses to new technology. It is particularly important that the engineering community should involve the human factors specialists at an early stage, in the development of the generic technology, in the specification of the requirements for a particular application and throughout the development and testing phases.

Consideration should be given to achieving commonality, at least at a functional, human interface level, between systems applied to different helicopter types. An interesting question to be considered at the design stage is how intuitive the system should be. This has implications for the levels of crew skill and training that are required and can be sustained.

Adequate allowance must be made for prototyping and simulation. An aim should be to make systems more adaptable, accepting that systems may not be right first time. Introduction of change into the cockpit environments of many current helicopters is inhibited by the inflexibility of both the hardware and the software. In terms of cost and timescale, the regulatory and certification processes can also be an impediment.

An essential part of both the development and T&E processes is a safety and risk assessment. Whilst the engineering assessment is purely deterministic, the question arises as to whether it is possible to take either a deterministic or even a probabilistic approach when human factors are involved. Some organisations are said to be looking at fault tree approaches to assessing human factors issues. Integrity and failure analyses are essential.

It is important to understand whether the introduction of new technology leaves the overall system more vulnerable to failures. This must be part of the overall risk assessment, which needs to be conducted in parallel, not sequential to, the system development and test programme.

The response of the human operator to a new system will be a function of not only the new technology per se, but also of its interaction with other systems and the environment in which both technology and human are required to function. Thus the operator will be multi-tasking and will be subject to a "distraction environment" e.g. noise, vibration, hot /cold, NBC clothing, and physical and mental fatigue. This overall operational environment should be represented as far as possible in any testing and evaluation of the new system, whether it be through simulation or in flight. From the HF point of view, the T&E process should consider a number of aspects of the human response including requirements, capabilities, characteristics, limitations, and behaviour.

An important output from the development phase should be the definition of the necessary training and qualifications for the crewmember. These can be expressed through training needs analysis. They should be reviewed as experience of the new technology is acquired during T&E. Training should address not only the use of the new system but also its limitations of use.

Introduction to Service

In moving from the T&E process towards introduction to service, the new technology or system should be introduced in a limited area for a trial period and reviewed before rolling out fleet-wide. This review should include consideration of crew selection and training as well as safety and other human factors issues that may have arisen. The programme budgets should allow for the possibility of the need for changes and consequent re-certification work at this stage. The operating organisation should maintain a database of human factors issues as reported in post-flight reports, debriefs, confidential reporting systems, etc. Lesson learned should be taken on board in the evolution of training associated with the new system. Finally the need for continuation training must be defined and implemented.

Human Factors

Throughout all stages of the processes discussed above, the human factors concerns must be addressed. Major points are summarised below.

It is important to understand the characteristics of the user in terms of both physiological and psychological effects. These include:

- Mental capabilities: memory, information processing, vocabulary, decision making.
- Hearing: discriminability, damage levels, range.
- Vision: visual acuity, range, discriminability.
- Body size: dimensions, range of movement.
- Physical capabilities: lift limits, fitness, reaction time.
- Variability between individuals, both physically and mentally.

From a human factors point of view, core issues are the orderliness and structure of information provided to the operator, the nature of his/her decision making, and the means by which performance in decision-making systems may be assessed. The modelling and prediction of human response is inherently difficult.

Modelling and simulation methods have improved to the point where they can make a major contribution to the evaluation of the human response to new systems, in a reasonable representative environment in terms of interaction with other systems and the external influences. However, some level of flight test is likely to be inevitable in order to test the equipment / human interaction under the full stressing environment. In all the testing, the measures of effectiveness need to be well conceived and appropriate to the overall task so as to be sensitive to the physical and mental interactions.

Multi-sensory integration is not fully understood. Humans will tend to switch the focus of their attention between sensory systems according to the demands of the instantaneous situation. For instance inputs via a haptic system operating on the torso may be missed in moments on extreme concentration on the visual scene. Similarly, difficulty in listening and talking simultaneously in stressful situations may be an issue. As far as possible, the effect of such issues on overall operational effectiveness should be assessed during development and T&E.

Regulatory Issues

For the regulators, it is recognised that many regulations exist, but are they effective? For instance, JAR 25 tries to achieve elimination of human factors risks by enforcing good design practices.

Regulations will tend to be reactive to new technology. A good example is the tilt rotor aircraft, with issues such as the type of pilot's qualification (fixed or rotary wing) and the standardisation of pilot's inceptor configuration (as exemplified by the change from a fixed-wing throttle configuration for the left-hand inceptor on V22 to a helicopter collective configuration on the AB 609).

At an early stage, there needs to be an identification, recognised by all parties, as to the responsibilities of the various parties, particularly the aircraft design authority and the operator. In the case of a highly integrated system, the Design Authority must be the lead, in that the interactions of the new system with the existing systems must be understood at both the engineering and the human factors levels. If the new technology is essentially an add-on, for instance a piece of personal equipment, then the operator may be the lead. In either case, there should be oversight by the regulatory authority to ensure that the responsibilities are owned and fulfilled by the appropriate party.

The definition and enforcement of training requirements is an important aspect of regulation.

Conclusions and Recommendations

The introduction of new technology on to civil and military helicopter platforms has not always been a total success. While the equipment may have been effective in its conceived role it has sometimes introduced unforeseen human factors issues.

A wide range of new technologies is reaching maturity and could be introduced into helicopters to the potential benefit of operational capability and safety.

However, to realise this objective the whole community of engineers, human factors specialists and regulatory authorities needs to work together throughout the development, certification and in-service phases to ensure that the technology is indeed a help not a hindrance.

Acknowledgements

The authors wish to acknowledge the contribution made to the RAeS conference by the presenters and panel members listed at Annex A. However the current paper represents the views of the authors.

References

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Annex A.

Conference Programme, 4 February 2004

"Technology – Help or Hindrance?"

Session 1: Setting the Scene: – How High-tech has Helped and Hindered

Chairman's Introduction
Mr Dave Tyler, Head of Avionics & Electrical Systems, Westland Helicopters Ltd, UK

An Overview of the Problems Faced by Civil Operators
Mr Nigel Talbot, Civil Aviation Authority, UK

An Overview of the problems faced by Military Operators
Cdr Steve Daniels RN, Aircraft Test & Evaluation Centre, Boscombe Down, UK

Human Factors Overview
Col Malcolm Braithwaite, Director AAvn Aviation Consultant, UK Army.

Session 2: Advances in Technology – A View over the Hill

Mission Management Systems
Mr Chris Bartlett, Chief Technologist – Avionic Systems, BAE Systems, Rochester, UK

Vision Systems – NVGs and Beyond
Mr Adrian Ball, Technology Chief, QinetiQ, UK

Non-Visual Sensory Input / Output
Mr Paul Collins, Dstl, UK

Haptic Systems
Mrs Heidi Castle, Advanced Technology Centre, BAE Systems, Filton, UK

Advances in Flight Control Technology
Mr Jeremy Howitt, QinetiQ, UK

Advances in Engineering Support Technology
Mr. Tony Blanchard, Quality and Safety Manager, Bristow Group

Session 3: Technology Integration Process - Open Discussion led by Panel.

Chairman's Introduction
Mr Tim Cansdale, Team Leader / Rotorcraft Systems Engineering, Dstl, UK

Panel Members:

Mr Dave Tyler, Head of Avionics & Electrical Systems, Westland Helicopters Ltd, UK

Mr Bob Taylor, Leader / Human Sciences, Air Systems Dept, Dstl, UK

Dr Julia Scriven, Aircraft Test & Evaluation Centre, QinetiQ, Boscombe Down, UK

Mr David Haddon, Civil Aviation Authority, UK

Chairman's Summary and Conclusion
Mr Tim Cansdale, Team Leader / Rotorcraft Systems Engineering, Dstl, UK