Context and synopsis

Paper 57

ENHANCING HELICOPTER MISSION EFFECTIVENESS

David Byrne

Helicopters feature prominently in modern military engagements: they provide versatile transport, flexible reconnaissance and communication, and a stable weapon platform. On the battlefield in particular, their manoeuvrability brings tactical advantage. However, if the helicopter's basic capabilities are to be exploited to the full, there is a continuing need to ensure that the products of modern technology are being used to benefit operational effectiveness.

Helicopter operational effectiveness can be broken down into two main parts: being able to carry out the required tasks and to survive whilst doing so. The technologies to support both aims fall broadly into three main areas: mission-planning, day/night all weather capability, and integrated helicopter survivability.

The task of **mission planning** is to define the routes and engagement profiles for the forces available. The aim of introducing automated computerised tools is to reduce the time spent on mission planning whilst increasing mission effectiveness. However if operations are to be carried out successfully and cost-effectively they cannot be allowed to depend on the weather or time of day. **Day/Night All Weather** (D/NAW) research and technology demonstration is directed to enabling nap-of-the-earth operations to be carried out at all times. The third area, **Integrated Helicopter Survivability** (IHS) is concerned with the integration of the helicopter's Defensive Aids Suite and other associated systems, and with identifying the most appropriate survivability measures suited to helicopter protection.

This paper discusses how current DERA research into these developing technologies can be applied to enhance the operational effectiveness of the helicopter of the future by way of mission planning and D/NAW.

Better mission planning will enable aircraft to avoid unnecessary trouble. Improved day/night all weather technologies will enable aircraft to hide behind terrain or benefit from poor visibility.

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Abstract

Military helicopters provide versatile transport, flexible reconnaissance and communication, and a stable weapon platform. On the battlefield in particular, their manoeuvrability brings tactical advantage. However, if the helicopter's basic capabilities are to be exploited to the full, there is a continuing need to ensure that the products of modern technology are being used to benefit the helicopter's ability both to carry out the required tasks and to survive whilst doing so. This paper discusses how current DERA research into developing technologies can be applied to enhance the operational effectiveness of the helicopter of the future.

This is based on a paper of the same title that appeared in the Journal of Defence Science October 2000 issue, by D T Byrne and A Lines.

1 Introduction

The helicopter's unique tactical manoeuvrability is central to the success of many modern military operations, and bringing together all battlefield helicopters of the Army, the Air Force, and the Royal Navy's commandos under one command (the Joint Helicopter Command (JHC)) recognises this importance. There is a matching and continuing need to apply modern technology both to exploit the helicopters basic capabilities and to enhance its operational effectiveness.

Helicopter mission effectiveness can be broken down into two main parts, the ability to do the required tasks and the ability to survive whilst doing them. The technology in the MOD's Applied Research Package 3d applicable to both of these aims falls broadly into three main projects within DERA, mission planning, Day/Night All Weather capability and integrated helicopter survivability. This paper investigates how the current DERA research into these developing technologies can be applied to enhance the operational effectiveness of the helicopter of the future.

The task of **mission planning** is to define the routes and engagement profiles for the range of forces available. The aim of introducing automated computerised tools is to reduce the time spent on mission planning whilst increasing mission effectiveness. However if operations are to be carried out successfully and cost-effectively, they cannot be allowed to depend on the weather or the time of the day. **Day/Night All Weather** (D/NAW) research and technology demonstration is directed to enabling nap-of-the-earth operations to be carried out in any visual environment. The third area, **Integrated Helicopter Survivability** (IHS) is concerned with the integration of the helicopter's Defensive Aids Suite and other associated systems, and with identifying the most appropriate survivability measures suited to helicopter protection, this area will not be covered in this paper.

2 Mission Planning

Tactical Mission Planning for Helicopters is becoming increasingly complex as their role is extended to accommodate deeper, more aggressive, high tempo operations across extended frontages and against a dispersed enemy using advanced weapon systems. In the future, operations will be joint service and probably undertaken as part of a coalition force. This will demand a high degree of co-ordination and interoperability and will require the facility, where possible, to access common information sources.

Within this demanding environment the generation of high quality mission plans will be of increasing importance in the co-ordination of complex multi-aircraft missions. Such mission plans must meet the demands placed on them by the doctrinal commitment to co-ordination, precision, stealth and operational tempo. Mission plans must take into consideration the array of constantly updated tactical information available and must be capable of rapid revision and re-planning both on the ground and in the air [1].

Complex plans, which take account of this increasing number of dependent variables, cannot be readily produced without recourse to electronic Mission Planning System (MPS). The deployment of MPS which are fully fit for purpose will be crucial if information overload is to be avoided and full mission effectiveness is to be ensured.

Hitherto, the majority of MPS development has focused on the needs of fast jets. As a result, many of the MPS in the market place have been optimised for an operational environment very different from that experienced by battlefield rotorcraft. Despite this the belief persists that with minor modification and parameter changes the functionality of a rotorcraft MPS can be met by adaptation of existing fixed wing MPS. The adequacy of this approach is questionable as fixed wing MPS rarely match the very different information needs of rapid manoeuvre, low speed, low altitude tactical rotorcraft missions.

MPS functionality

It is proposed that MPS can be deployed to support at four distinct levels of command:

- Theatre level planners. These are designed to support the top-level strategic military options when developing campaign plans and evaluating the logistic requirements.
- Formation level planners. These are employed to assist in battle planning and are capable of supporting joint and combined force co-ordination at formation level.
- Mission Level Planners. These support the preparation of tactical pre-mission plans for the deployment of specific platform types.
- Platform Level Planners. These are integrated within the platform and support the plan execution, replanning and retasking en-route.

For the purposes of this paper, consideration has been limited to systems which provide support at the Mission and Platform tasks as this reflects the level at which MPS are traditionally held to operate. The following functionality must be provided by a MPS if it is to support the ‘end to end’ generation and execution of a mission plan:

- Data Capture: the receipt of orders and the acquisition of intelligence information concerning own and enemy force dispositions, both current and predicted.
- Plan Development: tactical situation assessment, detailed route planning, aircraft configuration, plan rehearsal and mission briefing.
- Mission Execution: the mechanisms that allow a pre-mission plan to be transferred to the aircraft and modified en-route in accordance with the prevailing military situation.
- Post Mission Debriefing: the capture and dissemination both vertically and horizontally through the command chain of information gathered during the execution phase.

Research by DERA has focused on the development of computerised tool sets to aid mission plan development. A key component in the tactical planning phase for reconnaissance, surveillance and engagement type (mission) activities is the selection of Battle Position and Observation Positions in conjunction with co-ordination of their associated tactically secure access routes. This must take into account the degree to which the aircraft is masked by culture, and the presence or otherwise of a backdrop which will avoid sky-lining. Each of these is critical to tactical helicopter operations. Three tool-sets using advanced computerised decision aids are being developed by DERA which facilitate these calculations.

The first of these innovations is the development of decision aiding tools which are able to exploit digitised topography to generate Observation Positions and Fire Positions automatically. When these are integrated with advanced route planning tools for the rapid generation of tactical routes, advising on both altitude and lateral movements, the operator can be presented with a spectrum of options which are open to them to fulfil their mission. Tools have been developed to aid the assessment of three key criteria: line-of-sight, backdrop and masking.

Line of Sight (LoS)

LoS is the ability for the target to be seen from a particular vantagepoint, i.e. not to be occluded by either terrain or landscape culture.

Masking

For thousands of years man has known that one of the greatest techniques in war is the ability to surprise the enemy. Some typical ways of stealthily approaching the enemy are hiding in woodland, manoeuvring deep in valleys or moving covertly by night. Using woodland is known as soft masking, using terrain is known as hard masking. Helicopter mission profiles of today are optimised by the use of both hard and soft masking. An example of hard masking is shown is figure 1 and figure 2 shows soft masking.

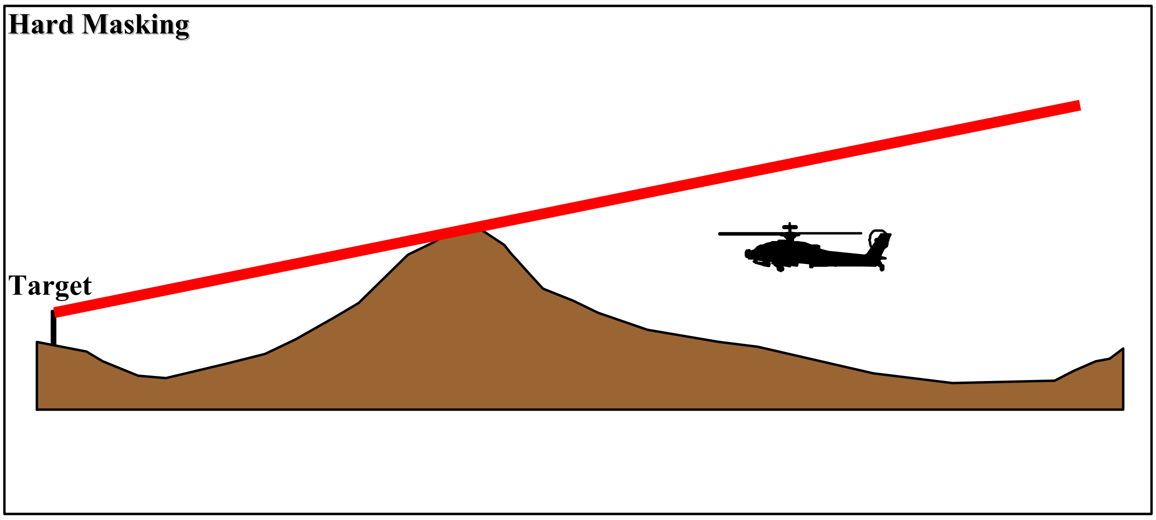

Figure 1: Showing hard masking.

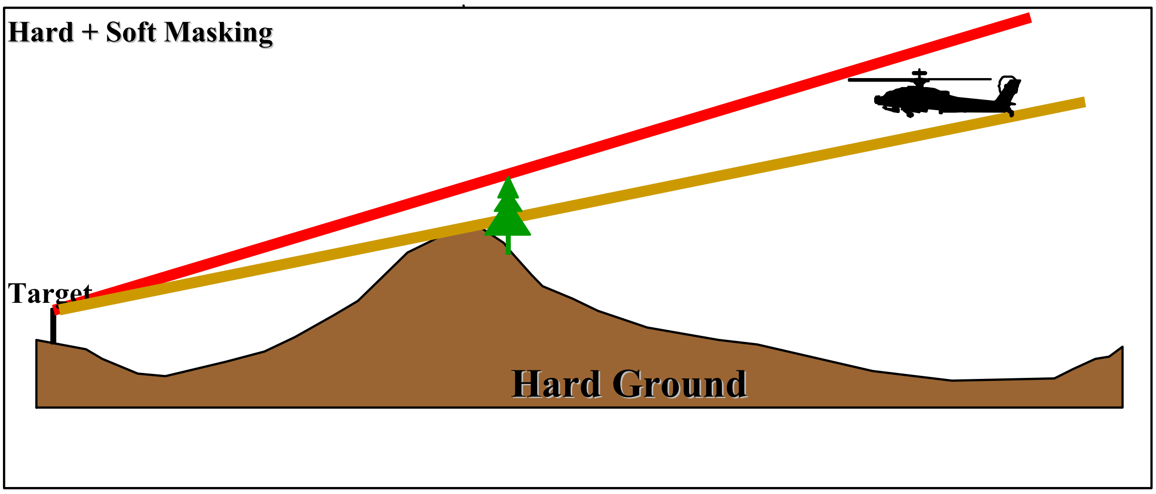

Figure 2: Showing hard and soft masking. The helicopter is making maximum use of the masking available.

Both hard and soft masking aid the ability to move stealthily. The main advantage with hard masking is the protection against enemy fire that arises, whereas soft masking offers better camouflage and is ideal for reconnaissance and surveillance tasks. To optimise the cover provided by the masking the helicopter should be as close to the 'front edge' of the mask as possible. A mission that uses both hard and soft masking is advantageous and computerised tactical mission planning decision aids are currently being developed by DERA to take account of this.

Backdrop

Although masking can offer a stealthy approach to and within a tactical location, once the aircraft performs a bob-up (or bob-sideways) manoeuvre to gain LoS to the target, the aircraft may become exposed. This exposure is intensified if, during a bob-up manoeuvre, the aircraft becomes sky-lined. This means that, when viewed from the target, the aircraft is silhouetted against the sky. This greatly increases the aircraft's visibility and therefore also its vulnerability.

From a tactical perspective it is advantageous if positions from which the bob-up is performed can offer low contrast backdrop once LoS is achieved. Not only does backdrop prevent skylining, but the background clutter will also reduce the aircraft's signature and improve the stealthiness of the manoeuvre. This is shown in figures 3 and 4.

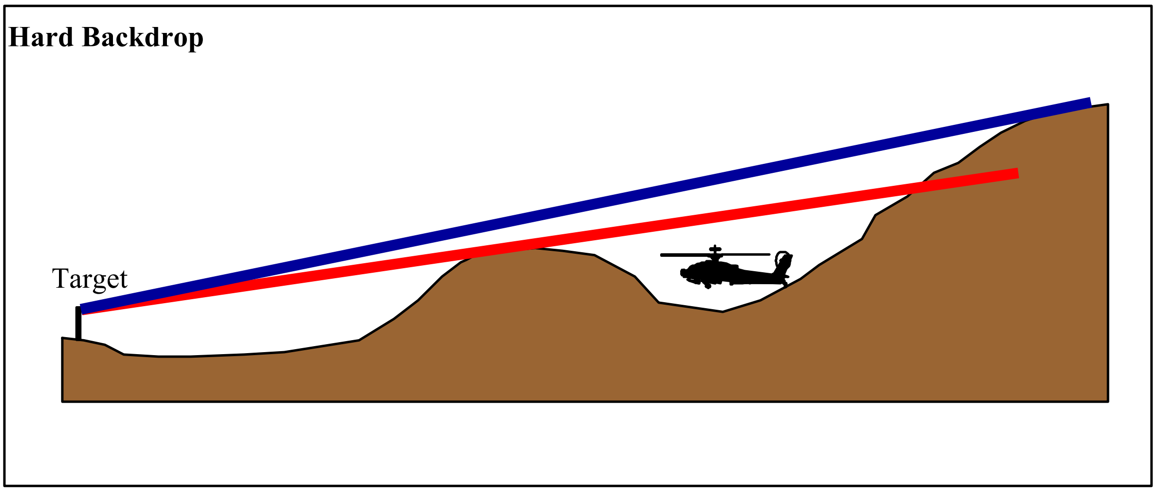

Figure 3: Showing a hard backdrop.

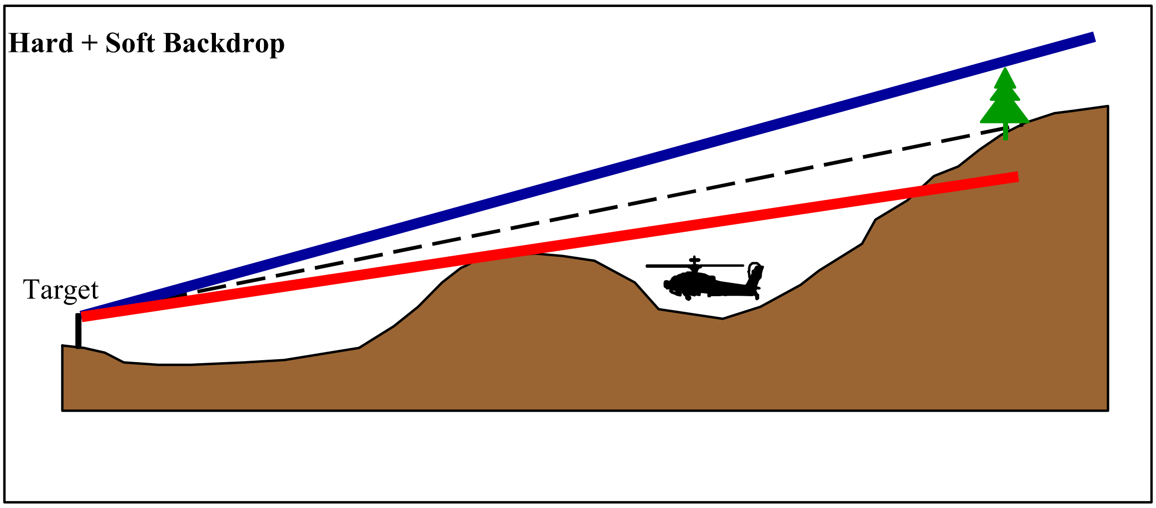

Figure 4: Showing the benefit of a hard and soft backdrop. The helicopter could be much higher without the risk of skylining. Here the helicopter can get far nearer the target without greatly increasing its vulnerability.

The second innovation takes the form of a tactical planning tool which will allow the automatic generation of a search plan designed to ensure that a specified area of interest (AOI) can be 'cleared' in a co-ordinated and stealthy manner [2].

Finally, prototypes are currently being developed for tools which will facilitate multi-aircraft co-ordination and potentially theatre wide deconfliction taking into account the evolving dynamic operational scenario.

A mission planned satisfactorily may still be compromised when in flight because of poor visibility. Current research under the D/NAW programme addresses this problem and is fundamental to the enhancement of mission effectiveness.

3 Day/Night All Weather Operation

In order to survive in hostile threat environments helicopters often operate at low level Nap of the earth (NoE) as illustrated in Figure 5 & 6. Typical hazards to low-level flying in poor weather conditions are trees and wires which are common causes of flying accidents. Current Day, Night All Weather (D/NAW) applied research is attempting to develop and assess technologies to improve operational capability in degraded visual conditions.

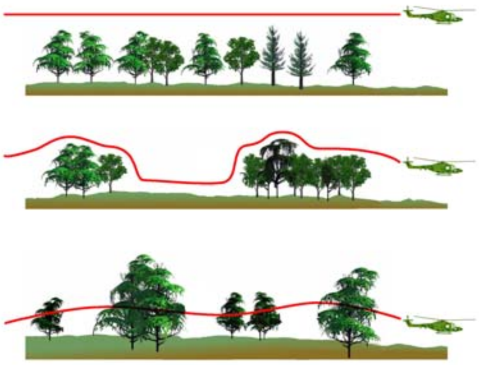

Figure 5: Low level transit 100-250ft agl (top), Terrain transit 50-100ft agl (centre), NoE transit <50 ft (bottom*)*

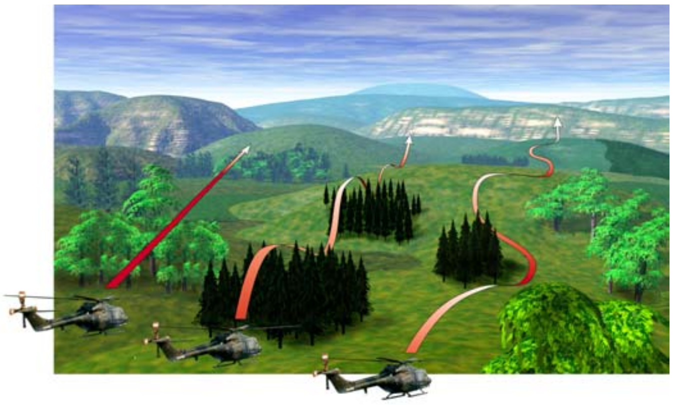

Figure 6: Low level transit (left), Terrain transit (centre), NoE transit (right)

In good day time visual conditions the pilot is able to use his unaided eyes to extract information from the outside world to perform the necessary flying tasks which include, primarily, flight control, guidance (including collision avoidance) and navigation. As visibility degrades the pilot's ability to extract the necessary information for each task reduces with a consequent reduction in performance and safety. Research at DERA [3] is investigating how the necessary information to perform each flying task can be gathered using sensing technologies and presented effectively to the pilot. A key component of this work is to understand the trade-offs between a wide variety of sensing and display technologies and develop reliable methods for quantifying their relative contributions to a pilotage information system. Examples of technologies which will contribute to the overall aim of 'Intelligent Flight Path Guidance' are summarised in Figure 7.

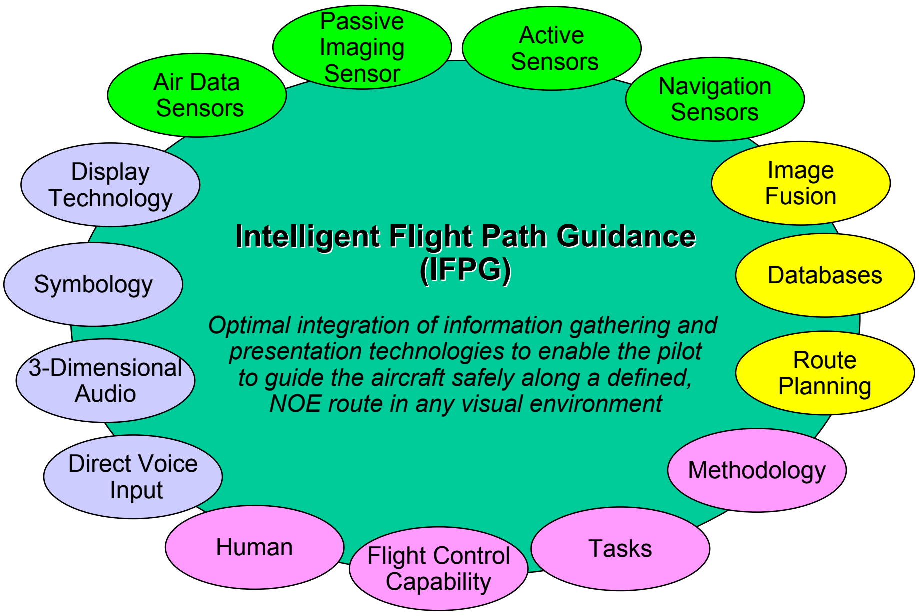

Figure 7: Intelligent Flight Path Guidance components

Pilot Information System

In conventional battlefield helicopters the pilot is a key part of the overall flight control system, and uses his eyes to extract information from the outside world scene (using visual cues such as differential motion parallax, macro and micro textures, closing rates to features and feature recognition) to control, guide and navigate the aircraft. At night time this 'naturalistic' form of information presentation may be provided in part by night vision goggles (NVGs). However, these have reduced resolution and field of view, are monochrome and require significant training and experience to interpret the imagery they provide reliably; hence they impart a much greater attention demand on the pilot. NVGs also rely on a minimum ambient light level and offer no adverse weather capability.

In such demanding conditions the information to control the aircraft could be extracted from alternative imaging sensors such as thermal imagers or passive millimetric imaging which promises a true capability to see though fog. However, each sensor will also have limitations such as resolution and field of view which will directly affect the pilot's ability to extract all the necessary information. The imagery may be presented either head down using cockpit displays or head up using, for example, a helmet mounted display and head steered sensor (the so called 'visually coupled system'(VCS)). The former 'head-down, eyes-in' approach provides only limited situational awareness around the aircraft, whereas the VCS approach is 'head-up, eyes-out' but is complex and can lead to disorientation due to multiple head, aircraft and outside world references.

To improve the presentation of information a common technique is to overlay symbology on the sensor image, as for example, in fixed wing head-up displays or the WAH-64 Apache Integrated Helmet and Display Sighting System (IHADSS). This approach is complicated by the phenomenom of cognitive capture where the sensor imagery and symbology exist in separate visual reference frames and the pilot may become fixated on one or the other to the detriment of the overall flying task which requires information from both simultaneously. Furthermore, the level of interpretation or 'mental arithmetic' associated with using the symbology will depend on the symbol design. Human factors research at DERA has attempted to reduce the attention demand by designing 3-dimensional, perspective symbology, conformal with the outside world and hence contained within the same reference frame as the imagery. Further display techniques have made use of peripheral, textured symbology which attempt to exploit the human visual motion system rather than requiring the eye to foveate on a confined part of the display.

Further methods for managing the pilot attention requirement during demanding D/NAW conditions are promised by technologies such as Direct Voice Input (DVI) and 3-dimensional audio. DVI will allow many head-down tasks such as manipulating mission systems or radios to be completed by speech recognition, allowing the pilot to concentrate on the primary flying tasks. 3-dimensional audio technology enables audio cues to be spatially separated in azimuth and elevation and promises an effective means of partitioning audio information from, for example, different radios, collision warnings or weapon cueing. Effective use of the human aural channel also promises to reduce the load on the visual channel.

Flight control task

To control and stabilise the aircraft in free space the pilot primarily extracts velocity, acceleration and attitude information from the outside world or from a sensor image. As visual cues reduce from either effective control of the helicopter will be compromised. An alternative strategy is to use velocity, acceleration, and attitude provided by parametric sensors, such as accelerometers and gyros within an Inertial Navigation System, which detect the body axis movements of the aircraft. Such information can be displayed explicitly using instruments or in the form of symbology overlaid on the passively sensed image.

A further technology option to aid the flight control task is to improve the flight control system to maintain stability automatically. This promises significant reductions in the pilot attention demand for the control task and will reduce the need to display control task information. In the longer term, the use of improved flight control systems and active control technology is likely to fulfil the control task requirement, and hence represents an important contribution to a D/NAW system. In the interim, the trade-off between limited authority flight control systems and displays is an ongoing area of D/NAW research in DERA.

Guidance task

Guidance is concerned with avoiding the ground and obstacles on the flight path. Guidance information can be gathered in a variety of ways:

- Ground-based mission planning: knowledge of terrain, high trees, pylons, cranes, and other tall man made structures. Also daylight reconnaissance by spotter craft or unmanned air vehicles (UAV's) marking obstacles on a digital map/database.
- The in-built navigation system of the aircraft provides guidance in geodetic co-ordinates that may then be manually (or automatically) referenced to the features on the marked map.
- Secondary aircrew contributing to the pilotage task. Typically other crew can keep an eye on the map and can provide guidance to the pilot.
- The pilot spotting obstructions that are not on the map by using a combination of the naked eye and sensors.

In degraded visual conditions, the ability to detect obstructions on the flight path becomes more difficult and the use of onboard databases together with both active and passive sensors is being investigated. A variety of image processing techniques are being investigated to aid helicopter collision avoidance which include:

- multi spectral image fusion;
- polarisation;
- burst illumination.

The fusion of image intensified and thermal imagery has been investigated for some time to aid target detection, identification and weapon aiming. In the pilotage application however, fusion is required to improve the quality of the background imagery itself rather than extract hot spots from the background. Furthermore, in nap-of-the-earth flight, image fusion will have to cater for dynamic changes in lighting and shadow together with the associated variation in performance of the sensors, hence, an adaptive fusion algorithm will be needed with a real time performance. Examples of static fused images are illustrated in Figures 8a,b& c.

Figure 8a Visible

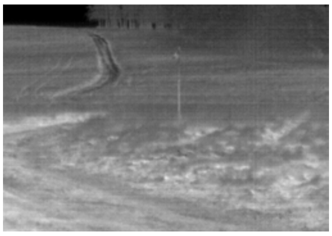

Figure 8b IR

Figure 8c Adaptively Fused

Research has indicated that man-made objects polarise both reflected and emitted radiation such that novel polarisation techniques can be used to extract and highlight potential obstacles from passive sensor imagery. Burst illumination techniques take this one stage further where short bursts of active illumination may improve significantly the information content of a passively sensed image.

Active sensors promise high resolution, high integrity parametric information to describe the terrain and obstacle environment ahead of the aircraft. A major difficulty with the exploitation of active sensor information has been the effective means of presenting it to the pilot. Existing obstacle avoidance systems based on LADAR have adopted traditional 2-dimensional symbology to provide a ‘window of safety’ above the obstacle plane.

However, this approach does not exploit the available data from the sensors as illustrated in Figures 9 & 10, and current research has investigated techniques for more effective presentation of such information using 3-dimensional perspective symbology, as illustrated in Figure 11. Such techniques, whilst developed using LADAR with minimal adverse weather capability, are generic and equally applicable to millimetric wave radar data with good adverse weather capability.

Figure 9: Barrow Hill photograph

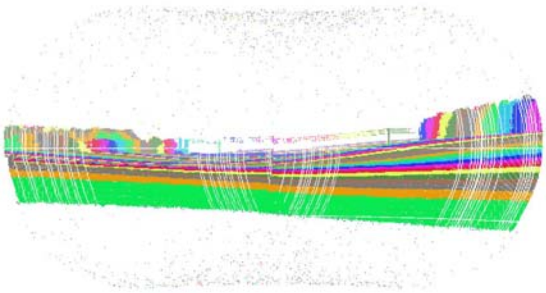

Figure 10: LADAR Colour coded range image

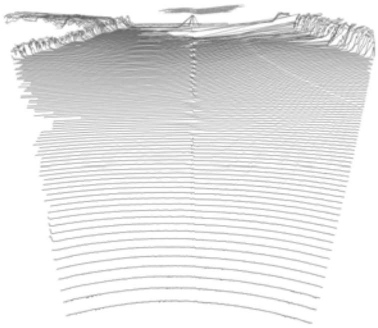

Figure 11: Processed perspective display

Navigation task

The navigation task has been defined in simple terms as determining the helicopter position in relation to its point of departure and points en-route in order to reach a known destination. Existing navigation systems position the aircraft in a geodetic reference system with numerical co-ordinates which may then be manually correlated with separate maps and outside world view to determine the position relative to ground features. The total navigation solution therefore depends on the accuracy of the navigation sensors and the completeness and accuracy of the map information. In degraded visual conditions the task of manual map reading and correlation becomes very difficult. A key requirement of a D/NAW navigation system will be to automate the correlation between the aircraft position provided by navigation sensors and the map information, by, for example, an integrated, moving map display.

The integration of the navigation system with map databases is unlikely to provide sufficient information alone to safely guide the helicopter along a NoE flight path in degraded visual conditions. The resolution and accuracy of the map information is key; for low level and NoE flight (below 250ft) the large features such as mountains and forests may be described with sufficient accuracy to enable adequate safety clearance margins. However, smaller features such as poles and wires are unlikely to be mapped and a separate guidance system capable of sensing obstructions along the flight path will be required.

Navigation technologies can be broadly divided into onboard sensors & systems, and off-board ground based or celestial systems. Off-board systems can be distinguished primarily by their need for communications transmissions with the helicopter and are therefore vulnerable to countermeasures. The primary form of onboard navigation system for military aircraft applications is the Inertial Navigation System (INS) which provides an autonomous navigation solution which is immune to countermeasures. INS provides high bandwidth kinematic data, such as angular rates, attitude, linear accelerations and velocities which, in an integrated D/NAW system, could also provide body axis information for flight control. Developments in INS technology may reduce the magnitude of the drift but in-flight correction using an independent navigation sensor system will be required.

In-flight correction to INS may be provided by a variety of navigation systems; the Global Positioning System (GPS) and Differential GPS (DGPS) are used commonly but are highly susceptible to countermeasures. Doppler velocity provides an autonomous means of deriving horizontal and vertical velocities together with position but requires active transmissions and is subject to cumulative error which limits its ability to update the INS. Terrain Relief Navigation (TRfN) may provide an autonomous solution but is currently unsuited to the ‘low and slow’ helicopter flight where it is unable to constrain the INS error sufficiently. Improvements in terrain elevation database resolution and/or interpolation algorithms may improve its accuracy. Existing off-board radio-based navigation aids are unlikely to provide sufficient accuracy and are highly susceptible to countermeasures. A further requirement is for absolute height above ground level. For low level operations, barometric height does not provide the accuracy, resolution and freedom from drift, hence a more accurate method of measuring height above ground will be required. This function could be provided by a radar altimeter or collision avoidance sensor (or sensor suite), for which both the control of active emissions will need to be considered.

The display of navigation information is an important component of the pilotage information system, in which the diversion of the pilot’s attention to head-down map displays should be minimised. A number of novel display concepts have been developed to allow head-up display of navigation information.

Pathways in the sky

Driving along a motorway is a relatively easy task as there are few obstructions, the motorway is expected to continue round the next bend and not to stop dead. However, flying Nap of the Earth (NoE) is different. A pilot could be flying through a firebreak in a forest and suddenly encounter a change of direction, steep terrain, or a fire tower. Little can be presumed in tactical NoE flying. A novel concept attempting to solve this problem is the pathway in the sky, which is like a virtual tunnel of safety to the pilot, and will provide him with a safe route through the terrain. An example is presented in Figure 12, where a pathway goes up the far hill. A limitation with the pathway concept is that it is reliant on database information which can be incomplete and inaccurate. An extension of the pathway concept is to generate its location from active sensor data, thereby providing a route which is known to be clear of obstacles.

Figure 12 also shows some other examples of perspective symbology [4]. The large yellow cube frame is the cockpit reference and tells the pilot where he is facing in relation to the cockpit. The arrow in the lower part of the screen shows the direction of the nose of the aircraft and its velocity and acceleration, and is used for the flight control task. The white dotted line marks the horizon and provides aircraft attitude whilst the red, blue, and white key shapes are conformal navigation waypoint markers.

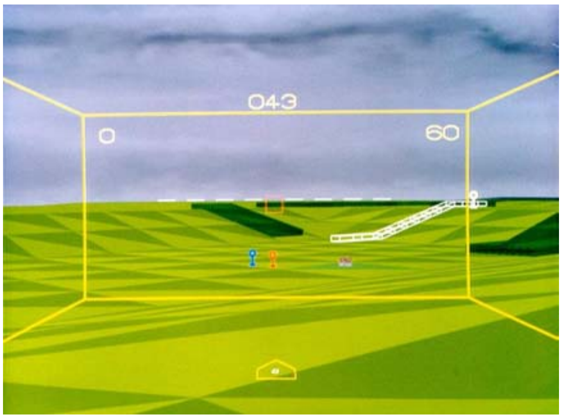

Figure 12: Examples of perspective display symbology.

The investigation of the information management issues associated with the integration of D/NAW technologies is being conducted, initially, in a controlled environment. Laboratory rigs and simulators are being used to ensure rapid prototyping and evaluation of integrated display concepts (although some concepts have already been demonstrated on a DERA Lynx helicopter). A further stage will be to construct a hardware systems rig which will provide risk reduction for the migration of display concepts into avionics hardware, prior to demonstration on a research aircraft under the CONDOR II Technology Demonstrator Programme. Clearly some of the technologies under consideration such as active sensors have implications for the total signature of the aircraft and hence, its survivability.

5 Conclusion

Introducing the technologies described throughout this paper has the potential to make future military helicopters increasingly operationally effective, however, integrating the many disparate systems on to the helicopter is a complex task.

Integrating the mission-planning suite into the helicopter's existing systems would allow the commander to update the mission profile at any time. Updated information could then be fed through to the aircrew and into the other airborne mission systems.

An understanding of the tactical information, helicopter capabilities and threat environment are needed for developing the mission plan. D/NAW technologies, including sensors and information displays will provide the capability to execute the mission under all environmental conditions, and hence the current studies are linked in a logical way and aimed towards Intelligent Flight path Guidance (see figure 13).

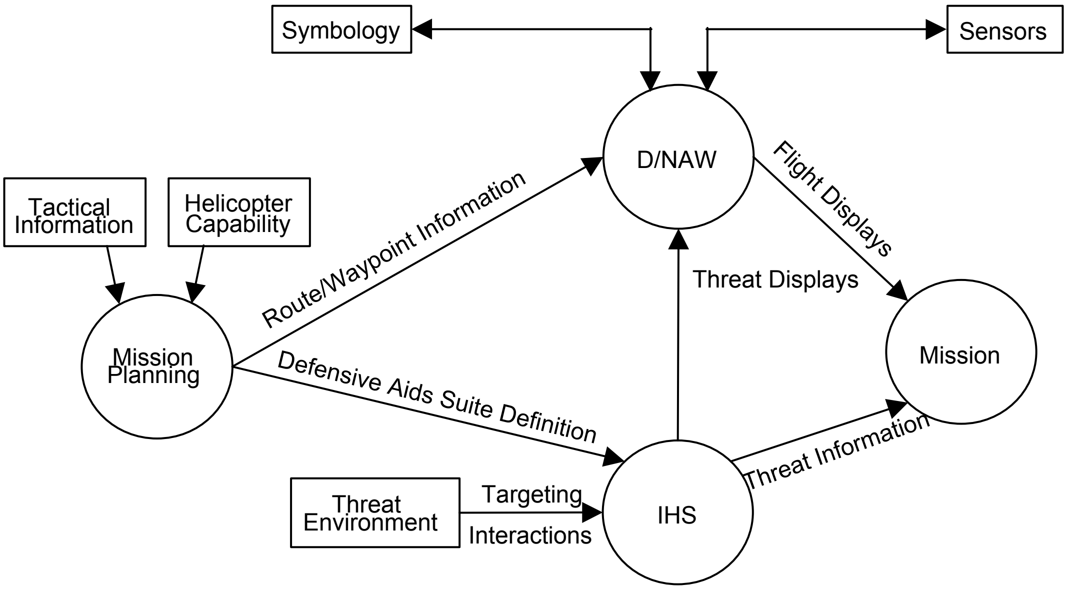

Figure 13: The data flow between the processes in the mission profile.

In comparison with a current helicopter being retrofitted or given a mid-life upgrade, the helicopter of the future will have fewer complex integration issues. Thus the current integration challenge may be more demanding than the integration challenge of the future.

Effective operations in the future battlefield will require a combination of techniques to enhance the mission effectiveness and survivability of helicopters. Better mission planning will enable aircraft to avoid unnecessary trouble. Improved day/night all weather technologies will enable aircraft to hide behind terrain or benefit from poor visibility.

6 Abbreviations

AAC	Army Air Corps
AAM	Air to Air Missile
Agl	Above Ground Level
AWR	All Weather Rotorcraft
CONDOR II	COvert Night Day Operations for Rotorcraft
DAS	Defensive Aids Suite
DEC	Deputy Equipment Capability
DGPS	Differential Global Positioning System
D/NAW	Day Night All Weather
DVI	Direct Voice Input
ETA	Estimated Time of Arrival
GPS	Global Positioning System
HMD	Helmet Mounted Device
HUD	Head Up Display
HIS	Integrated Helicopter Survivability
INS	Inertial Navigation System
MPS	Mission Planning System
NoE	Nap of the Earth
NVG	Night Vision Goggles
PAFCA	Partial Authority Flight Control Augmentation
STP	Spatial Temporal Probability
TM	Tactical Mobility
VCS	Visually Coupled System
WoS	Window of Safety

7 Acknowledgements

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