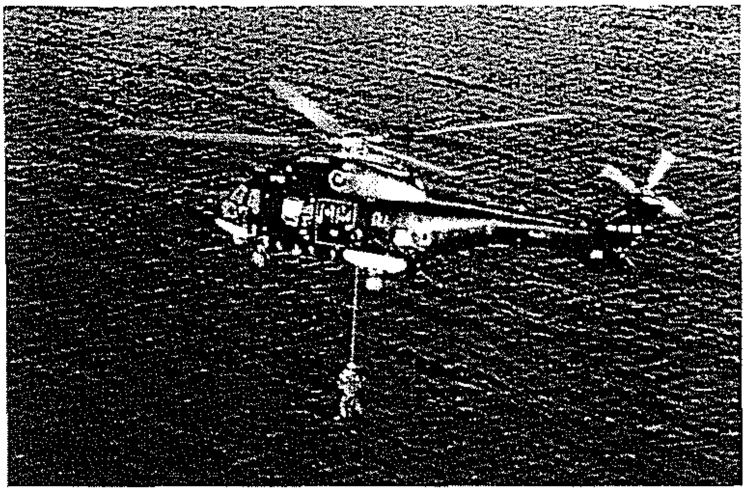
24th EUROPEAN ROTORCRAFT FORUM
Marseilles, France – 15th – 17th September 1998

REFERENCE : OP01

TITLE :DEVELOPMENT OF SAR CAPABILITIES ON THE AS 332 MK II HELICOPTER

AUTHORS :
E. MEISSIREL / V. SAINTAGNE - EUROCOPTER



The AS 332 MK II helicopter was IFR certified mid-1992 with a new avionics package called the Integrated Flight Control and Display System (IFDS). More recently, this avionics package was extended with the development of Search and Rescue (SAR) capabilities.

Eurocopter has considerable experience in this domain : SA 319 (Alouette), SA 321 (Super Frelon), SA 365 (Dauphin), SA 330 (Puma) and AS 332 MK I (Super Puma) helicopters have been carrying out SAR missions all over the world for more than twenty years. This experience and the feed-back from SAR operators were taken into account in the design and development of the SAR modes for the Super Puma MK II. The pilots' workload associated with SAR missions is very high, especially in adverse weather conditions. Therefore the main goal was to simplify and to optimize the operation of SAR modes in order to make them more "user friendly". Man-Machine Interface (MMI) aspects as well as Automatic Flight Control System (AFCS) control laws performance were identified as the main lines for possible improvement.

The development of SAR modes for the AS 332 MK II helicopter has now been completed. Validation/qualification flight tests have been successfully conducted and have shown that the improvement objectives have been met in full.

1. IFDS - GENERAL DESCRIPTION

1.1 Basic System

The AS 332 MK II helicopter is equipped with an avionics package known as the Integrated Flight Control and Display System (IFDS), based on a dual architecture (see Figure 1). Each half-system is made up of three sub-systems:

1.1.1 The Primary Reference System (PRS):

The core of the PRS is the Flight Data Computer (FDC) which consists of an integrated Attitude and Heading Reference System (AHRS) / Air Data Computer (ADC), providing:

- on the AHRS : attitudes, heading, angular velocities and accelerations ;
- on the ADC : indicated airspeed, vertical speed and altitude.

1.1.2 The Automatic Flight Control System (AFCS) :

The AFCS (see Reference 1) includes a four-axis digital computer controlling four seriesmounted electro-hydraulic actuators and four parallel electric trim actuators, and provides :

- automatic flight control (i.e. basic stabilization and upper modes) ;
- processing of flight envelope and power margin data,
- sensor monitoring.

1.1.3 The Display System :

The Display System is made up of two Smart Multimode Displays (SMD) fitted on the instrument panel, which ;

- include symbol generator resources ;
- display flight and mission data on the Primary Flight Display (PFD) and the Navigation and Mission Display (NMD) respectively ;
- act as a concentrator unit for navigation, radio-navigation and radio-altitude data.

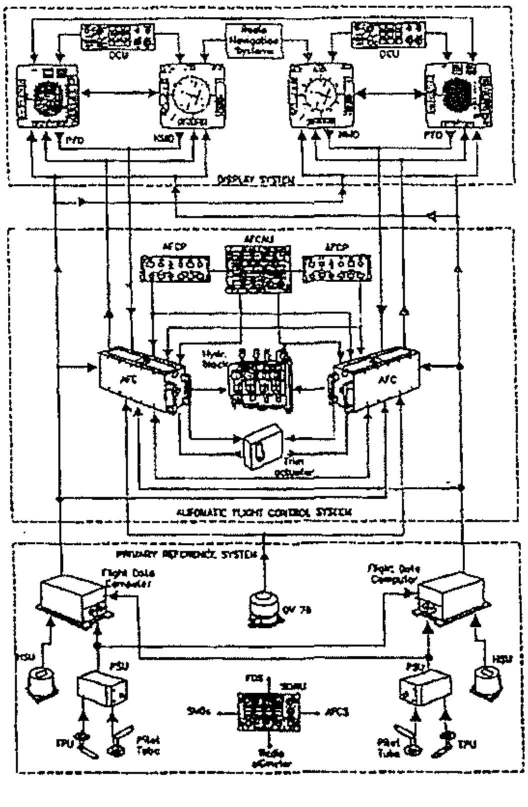


Figure 1 : IFDS general block-diagram

1.2 Changes in Conjunction with the SAR Modes

Adding Search and Rescue (SAR) modes, the functions of which are described in paragraph 2, results in the following changes to the IFDS architecture and component equipment items :

1.2.1 AFCS :

- software corresponding to the piloting laws for the new modes integrated in the digital computers ;
- two new engagement buttons : Fix + Transition Down (F/TDN) and radar Height + doppler Hover (HT/HOV) added on the Automatic Flight Control Panels (AFCP) (See Figure 2) ;
- two new "thumbwheel units" added to select the reference groundspeeds (for the pilot and the hoist operator) ;
- one joystick added for the hoist operator.

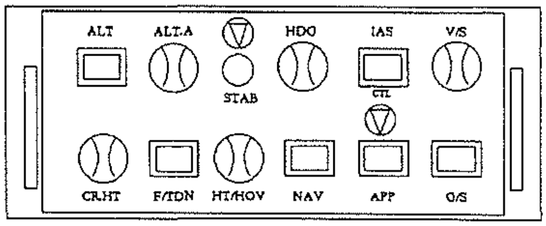


Figure 2: Automatic Flight Control Panel

1.2.2 Display System :

- two new symbol formats on the NMD screens corresponding to the PLAN and HOVER modes and two associated engagement buttons on the Display Control Unit (DCU) ;
- one joystick added to designate a point on the screen by moving a cursor on the PLAN and SECTOR formats ;
- provision to display the sensors on video format (e.g. FLIR) added, with symbols superimposed, if necessary.

1.2.3 Navigation System :

- horizontal guidance algorithms introduced to realize the search paths then to align the helicopter in the wind with respect to the person to be rescued.

1.2.4 Other Equipment Items :

- a Doppler radar installed. The longitudinal and lateral groundspeed data from this radar are acquired and hybridized by the FDC ;
- a second radio-altimeter installed, in accordance with safety requirements applicable to the automatic hover near the ground.

2. SAR MISSION PROFILE

2.1 Operational Requirements and Functions Required

The aim of a SAR mission at sea is to search for and localize someone lost at sea, then to hover at low altitude above this person in order to hoist him on board the helicopter.

The SAR mission can therefore be broken down into two main phases :

2.1.1 Search Phase :

The objective is the exact location of someone lost at sea by realizing a search pattern over an area in which he is likely to be. The equipment items required to meet this objective are :

- navigation/guiding equipment to implement the search patterns ;
- automatic flight control systems to ensure that these patterns are followed automatically in conjunction with other possible upper modes such as : radio-altimeter height hold, airspeed hold ;
- displays to monitor this phase of the mission in general ;
- high-performance search sensor data displays (e.g. : infrared cameras, localizing radar).

2.1.2 Rescue Phase :

Once the person lost at sea has been localized and fixed, the objective is to position the helicopter at low altitude, nose into the wind, above him. The equipment items required to meet this objective are :

- horizontal and vertical guiding/navigation equipment to generate a path, in the wind in line with the person to be rescued, then "transition down" to be in hover above him ;
- automatic flight control systems to follow these paths automatically, with provision for position correcting and accurate selection of the reference height and groundspeed ;
- displays well adapted to the hover mode, so that the automatic coupled modes can be easily monitored.

2.2 Difficulties Intrinsic to SAR Missions and Identified Lines for Improvement

2.2.1 Search Phase :

The capacity to pinpoint the person to be rescued rapidly is of vital importance. Part of the difficulty lies in the often very wide extent of the search area, which must be "combed" methodically.

Added to which, the meteorological conditions are often difficult, resulting in a very poor visibility which in itself hampers the localization of the person to be rescued.

Moreover, implementing high-performance search equipment (FLIR, search radar, locator, ...) in an integrated and coherent system can prove to be a determining aid to the success of this part of the mission and thus constitutes a top-priority line for improvement.

The same is true for the possibility of preparing the search pattern during the transit to the search area phase, in order to reduce the mission preparation time on the ground before takeoff, while ensuring a continuous transition to the active search phases.

2.2.2 Rescue Phase :

For this phase, the difficulty also lies in the meteorological conditions, which are often very bad and in conjunction with the complex piloting objective of getting into hover above a point which could well be mobile, can generate an excessive workload for the pilot.

The advantage of the automatic coupling of the AFCS modes to carry out this mission is obvious, especially as these modes generate accurate, precise paths and they are easy to use and do not generate an undue workload.

Close analysis of the remarks made by operators, in particular those in the North Sea used to carrying out SAR missions in extreme conditions with the 332 MK I, has led us to identify the following possible lines for improvement :

Acquisition of the Horizontal and Vertical Hover :

The descent and deceleration profile must be reliable, natural and fully controlled.

Flying over obstacles (e.g. ships) during the transition down must not generate excessive movements of the helicopter.

The arrival in hover must be perfectly controlled to ensure that the helicopter does not overshoot the person to be rescued (with the helicopter moving back in the final stage) nor undershoot the final set height (particularly dangerous at very low altitudes and in heavy swell).

The lateral guiding must be maintained up to arrival above the person to be rescued to prevent important lateral deviations in the final stages due to changes in the direction of the wind.

Hover Hold Above the Person to be Rescued:

The hover hold must be exact and not generate important movements of the airframe, even on heavy swell.

The pilot and the hoist operator must be able to modulate the groundspeed references easily, for example to follow a moving ship or a person drifting in the current, or to overcome a possible drift on the Doppler radar.

In the same way, it must be possible to carry out position adjustments to place the helicopter vertically above the person to be rescued, after a deviation caused by a gust of wind for example ; for this, the piloting laws must be sufficiently dynamic and the controls (e.g. : the hoist operator's joystick) adapted from an ergonomic standpoint (correct length of the stick, correct angular displacement and correct artificial feel law).

The heading into the wind must be held in hover, particularly during lateral translation movements to readjust the position.

A symbology specific to the hover flight must be developed to facilitate the monitoring of the helicopter path and the automatic coupling of the AFCS.

Procedures and Controls :

The procedures and controls to implement the SAR automatic coupling modes must be simplified.

By way of an example, on the Super Puma MK I, the automatic guided transition onto a person to be rescued requires 3 actions on different components in the system that must be carried out very quickly when flying over the person :

- "fixing" of the person to be rescued ;
- engagement of the horizontal guiding mode to align the helicopter in the wind with respect to the person to be rescued, on the navigation computer ;
- arming the Transition Down mode on the AFCS.

In the same way, following a moving point requires that the horizontal hover mode (HOV) be disengaged and replaced with a groundspeed hold mode (G.SPD).

Just for the AFCS on the 332 MKI , 6 engagement buttons are necessary to implement the SAR modes :

- CR.HT : radio-altimeter height acquisition and hold in cruising flight ;
- H.HT : radio-altimeter height acquisition and hold in hover flight ;
- T.DN : transition down to hover (automatic or guided) ;
- T.UP : transition up from hover ;
- HOV : horizontal hover hold ;
- G.SPD : groundspeed acquisition and hold.

3. ANSWERS PROVIDED WITH THE SUPER PUMA MK II

3.1 Procedures and Controls

The joystick has been redefined : new dimensions, new angular displacement and a new artificial feel law, together with more dynamic piloting laws (cf. § 3.3.2), enabling the hoist operator to carry out the necessary repositioning adjustments more easily.

The engagement of the "guided" transition mode to a person to be rescued after flyover and fixing has been simplified considerably : in fact, pressing the single F/T.DN button on the AFCP fixes the target (Fix function) and engages the Transition Down mode (T.DN function) both in the navigation and the AFCS computers.

Pressing the single HT/HOV button engages the horizontal (i.e. longitudinal and lateral) and vertical hover acquisition and hold functions ; thus it replaces the former Hover Height (H.HT), Hover (HOV) and Autonomous Transition Down (T.DN) modes.

Moreover, when the HT/HOV mode is engaged, it is possible to :

- adjust the height references on the AFCP and the groundspeed references on the pilot's thumbwheel unit (-10kt/+50kt longitudinal ; + or - 20kt lateral) and the hoist operator's thumbwheel unit (+ or - 10kt on both axes) : this makes it possible to realize the former groundspeed hold (G.SPD) function without engaging any other modes ;
- carry out the position adjustments using the cyclic stick beep function for the pilot and the joystick for the hoist operator (+ or - 10kt longitudinal and lateral).

Finally, the CR.HT mode, in the past allotted to the radio-altitude height hold in cruising flight (Cruise Height), is now extended to the entire speed range up to hover, with filtering and hybridization adapted to speed range.

In short, the 6 SAR mode buttons on the 332 MK I have been brought down to 4 on the 332 MK II and the functions have been increased :

- CR.HT : radio-altitude height acquisition and hold in cruising flight and hover ;
- HT/HOV : horizontal and vertical hover acquisition and hold ;
- F/TDN : "Fix" function (fixing the person to be rescued) and guided transition down ;
- T.UP : transition up from hover.

3.2 Display and Symbology

Taking advantage of the basic electronic instrumentation for IFR flight that is highly appreciated by both civil and military operators, the aim was to develop new functions more specifically dedicated to the SAR mission, as described in paragraph 2, and perfectly coherent with the basic instrumentation.

3.2.1 Search Phase :

A course that is being prepared can be displayed on the NMD in addition to the active course on which the guiding is in progress, so that the copilot can prepare the search patterns during the transit to search area phase.

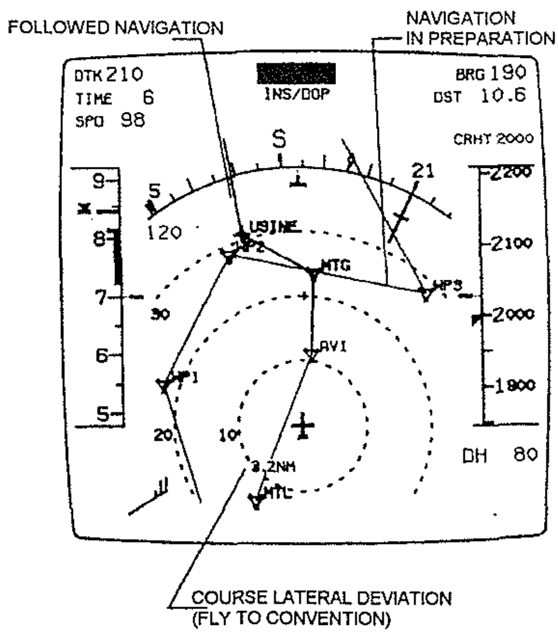


Figure 3 : NMD Screen -SECTOR Mode

Moreover, these courses can be displayed with respect to two different references :

- the current position of the helicopter via the SECTOR mode (see Figure 3) ;

- a position (a priori that of the person to be rescued) by means of the PLAN mode, developed for this purpose (see Figure 4).

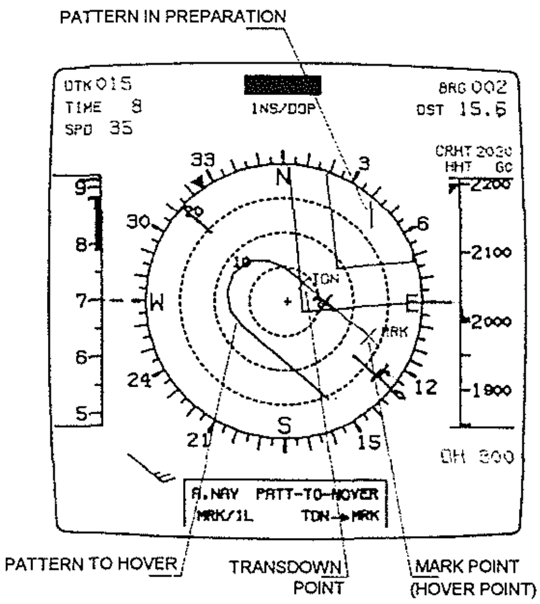


Figure 4 : NMD Screen - PLAN Mode

Once in the search area while following the patterns, the visual monitoring of the outside world by the crew can be completed, in the event of poor visibility. To this end, the data signals or images output by the search sensors such as the radar or FLIR cameras can be displayed alone or superimposed on the monitoring of the helicopter horizontal path on the NMD, by means of very simple controls.

3.2.2 Rescue Phase :

A totally new symbology has been developed for the overall monitoring of the hover flight (see Figure 5), with, as the objective, remaining perfectly coherent with the basic IFR instrumentation and in particular with the attitude symbology but at the same time adding substantial advantages with respect to the conventional electromechanical hover flight instruments :

- analog presentation of the longitudinal groundspeeds without the usual limits around 30kt ;

- analog presentation of the reference groundspeeds controlled by the AFCS ;

- superposition of the geographical position of the targeted hover point ;

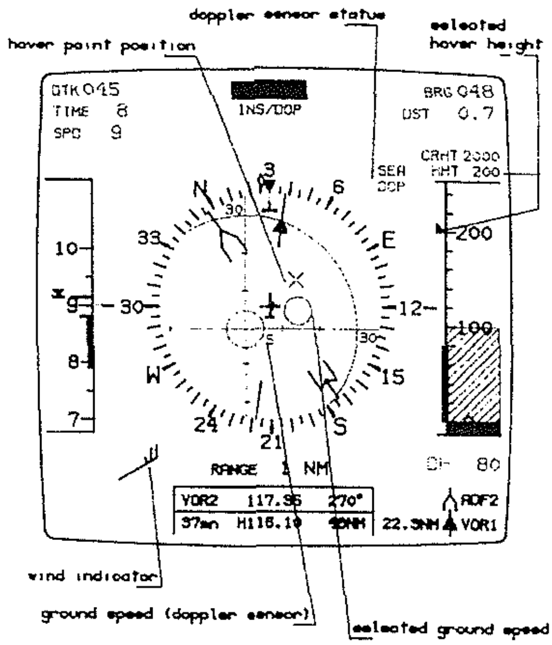


Figure 5 : NMD Screen - HOVER Mode

3.3 AFCS Control Laws

3.3.1 Horizontal and Vertical Hover Acquisition and Hold :

The descent and deceleration profiles have been completely redefined to include slaving to the optimum path, the parameters of which are perfectly controlled.

Hence, the descent path is defined by :

- a descent leg at 4.5° ground angle ;
- a parabolic approach ;
- a horizontal final phase.

Likewise, the characteristics of the deceleration profile are as follows :

- a constant deceleration phase ;
- a final exponential deceleration phase to the final hover.

The orders generated by these optimum paths are transformed by changing the axis systems (passage from an axis system related to the ground to an axis system related to the helicopter) into piloting references for the collective and longitudinal cyclic upper modes.

Slaving the position (speed nil controlled when the distance to the waypoint is nil) brings the helicopter accurately on to the targeted point, or even slightly forward of this point (provided that a "step" is included in the law) thereby avoiding any rearward movement in the final phase or a vertical descent directly over and without seeing the person to be rescued.

The undershoot phenomenon with respect to the final height selected has been definitively eradicated by including a correcting code for the reference altitude and vertical speed in the collective axis piloting law.

Finally, the lateral guiding improvement has been obtained by maintaining a zero cross track error XTK on arrival on the target, which was not the case with the existing systems for which the final phase in heading hold (HDG mode) could well generate important lateral deviations when there was a cross wind.

Figures 6 and 7 are taken from an in-flight recording on MK II. They represent the horizontal and vertical paths followed entirely automatically by the helicopter :

- "fixing" of the person to be rescued (FIX POINT) ;
- path into the wind in line with the person to be rescued controlled by the navigation system computer.
- engagement of the descent and deceleration profiles controlled by the AFCS (TRA POINT) ;
- perfect control of the arrival in hover above the person to be rescued (HOV point).

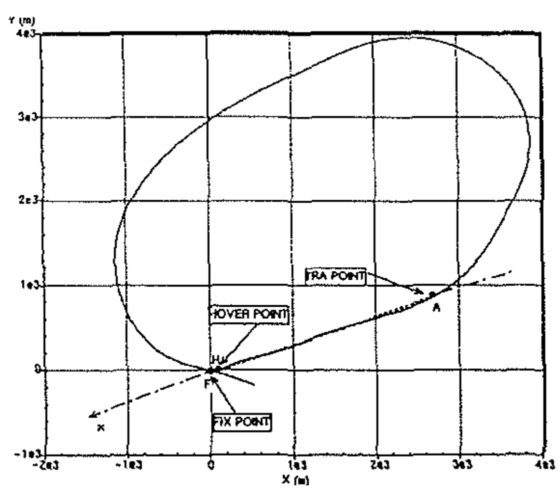


Figure 6 : Horizontal Guiding of the Helicopter

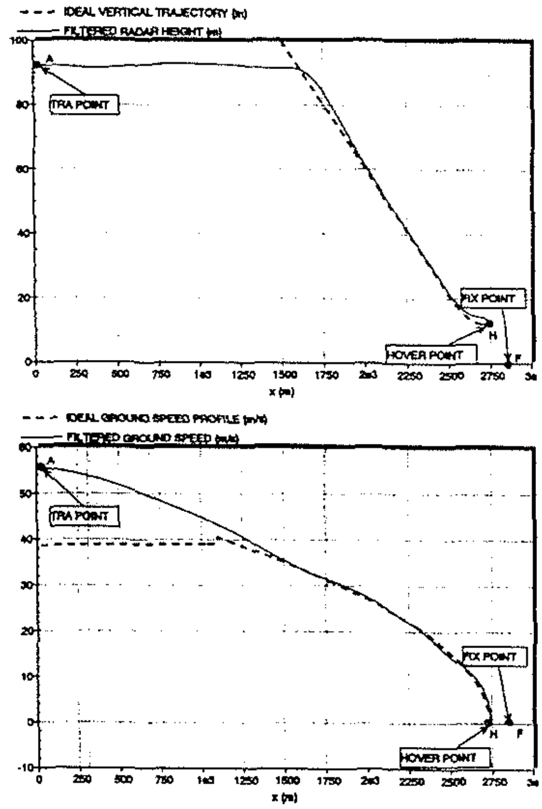


Figure 7 : Descent and Deceleration Profile

3.3.2 Hover Hold :

One of the main problems in the vertical hover mode is that of filtering through the swell, i.e. eliminating the interference due to the movements of the sea from the radio-altimeter height signal controlled by the collective axis upper mode.

The filters installed in the existing systems reached their limits in operation in high swell (e.g. : in the North Sea). Moreover, these filters, which do not usually have much damping, could generate hampering oscillations after flying over "sea relief features" such as small islands or ships.

A swell filter has been developed for the 332 MK II on the principle of hybridization of the radio-altimeter height data signal (that is stable at low frequencies but sensitive to the swell) and that of the vertical inertial acceleration (which has good dynamic properties, is insensitive to the swell but is affected by a static bias). The 4th order digital filter adopted achieves the best compromise between the following antagonistic objectives :

- good rejection of the swell irrespective of the spectrum (e.g. : -20dB attenuation for long sea swell such as that found in the North Sea) ;

- good stability to ensure correct behavior when flying over sea relief features ;

- high insensitivity to the acceleration biases.

As regards the horizontal hover, apart from the ergonomic changes to the hoist operator's joystick (cf § 3.1), the improvement lies in the dynamism of the piloting laws, considered to be too "sluggish" in the existing systems. Enhanced gains for the pitch and roll stabilization "small loop" in hover hold (HOV) mode enable more accurate attitude achievement on control via the beep switch or the joystick. The position adjustments to adapt to a moving target or correct the effect of a gust of wind prove to be easier, both for the pilot and the hoist operator.

Finally, the slaving of the heading hold mode by the yaw axis has been reinforced in hover in order to adapt to difficult meteorological conditions (e.g. : high cross winds) and to position adjustment maneuvers (lateral translation movement on the roll axis).

4. CONCLUSION

The SAR mission is undoubtedly among the most difficult for a helicopter crew to perform in view of the workload due to the extreme conditions in which it is often carried out.

During such a mission, efficient, easy to use piloting aids can prove to be a key factor to its successful completion.

It is for this reason that Eurocopter, as part of the ongoing policy of product improvement and customer satisfaction, made every effort in developing the SAR modes for the AS 332 MK II, to integrate all the possible improvements.

The resulting changes have now been tested and validated in flight and it has thus been proved that all the ergonomic and performance objectives have been met.

The AS 332 MK II - SAR helicopter being now in the delivery phase, no doubt, the operators will also confirm in the very near future the great efficiency of the implemented SAR modes.

REFERENCES

Conference Proceedings

/1/ A. Vaissière and E. Woirin, "Digital AFCS for AS 332 MK II Helicopter", in 13th European Rotorcraft Forum, September 1987, Paper 10.3.