Advanced Technologies for a future Heavy Transport Helicopter

Raphael Burgmair, Wolfram Koletzko, Wolfgang Kreitmair-Steck, Christian Weimer

All: EUROCOPTER Deutschland GmbH
D-81663 Muenchen, Germany
e-mail: wolfram.koletzko@eurocopter.com

Key words: ERF33, rotorcraft, technologies, flight controls, all weather, preforms, composite

Abstract: The next generation of heavy transport helicopters, operational 2025 to 2030, will need advanced technologies in many areas to be able to fulfill the ambitious, mostly military mission requirements for those helicopters. This type of aircraft will be deployed worldwide under nearly all metrological conditions and in unknown areas. These requirements lead to a demand for easier and safer handling of the helicopter.

Beside an optimized configuration of the vehicle, with modern lightweight composite materials to keep the empty weight as low as possible and ease the production of big structure elements, the flight controls and the situational awareness are the key issues.

Composite materials are going to be standard in future aircrafts like the Boeing 787 and the Airbus 350. Even if helicopters are using this type of material already in a quite wide range, improvements need to be made in the field of textile preforms and manufacturing processes to take full advantage of the material. The direction of the development will be outlined here.

Fly by wire controls and automatic flight control systems are already serial standard in the NH90. Eurocopter has also gained experience in fly by light technologies (ACT/FHS). Inter alia, this paper describes how the operator can benefit largely from an integration of fly-by-light or fly-by-wire and active flight controls.

Situational awareness is of utmost importance for the flight crew, especially in unknown areas and under adverse metrological conditions. Ideas of how pilots can be informed about topography, flight path and unknown obstacles will be discussed here. There are different kinds of sensors, 3D maps and navigation systems which need to be processed and displayed for the pilots in an intelligent way.

The selected examples should show how upcoming advanced technologies could positive influence the operational capabilities of future helicopters and how they could be integrated in the next generation of heavy helicopters.

INTRODUCTION

The next generation of very heavy helicopters above 30 metric tones, mainly for military use, will have to operate around the globe under nearly all metrological conditions and completely independent from any ground station.

Main missions of such a helicopter will be Conflict prevention, Crisis management, Emergency Evacuation and Rescue and Disaster relief during peace time. As we have learned from recent disasters like the Earthquake in Afghanistan and the Tsunami in Indonesia helicopters are required to deliver goods and material to the ravaged areas and to evacuate as much as possible people at once.

So vehicle related future requirements are vertical take off & landing without requiring an airfield, flying like an aircraft in between and a mission radius 3 to 4 times more than today with an improved range performance, more speed and more payload [1].

The size of the cabin is also given by the requirement for internal transport of military vehicles. As an example for the French and German Army are this existing and future (light armored) vehicles like Wolf, Wiesel, Dingo, Fennec, VLA, VBL and VAB. These vehicles weights vary from 2500 kg to 13000 kg.

The requirement for a radius of action of 500 km is providing the input for making a rough estimate of the necessary fuel. Depending on the number of engines (2 or 3) for such kind of aircraft it is possible to evaluate the MTOW with statistical data. In this case it will be about 32 to 35 tones.

Next step to enable the designer to select the right technologies is to look at the missions for the helicopter. If, in addition to the world wide operation under DVC, flights have to be performed in unknown terrain and NOE conditions, the navigation, flight controls and performance of the aircraft has to be designed accordingly. Consequently technologies are required providing the pilots with information about the accurate status of the situation and flight aids able to display them. The flight guidance and control system, including AFCS, should be capable to reduce pilots workload to a minimum for a safe operation of the helicopter.

How missions are driving technologies could be explained by an example. The mission is to penetrate some hundred kilometers into foreign unknown territory flying an altitude of 30 to 50 meters with a speed of 100 kts. This requires a powerful rotor system and drive train with excellent handling qualities and sufficient high g-load capability. It also makes some flight aids mandatory like Fly-by-Wire (Light), auto pilot and an obstacle avoidance system to enable the helicopter crew to perform the mission.

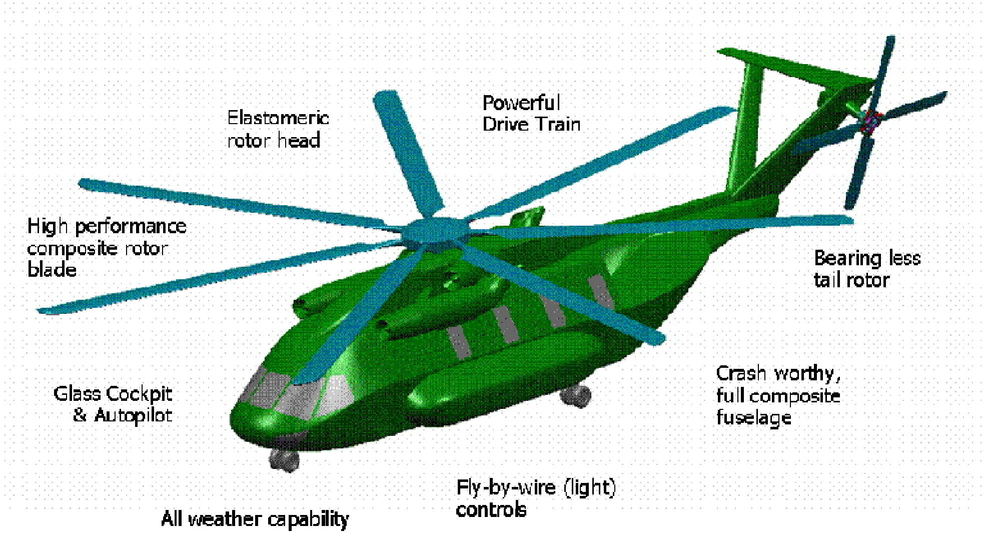


Figure 1: Technologies for HTH

To meet all future requirements the major HTH technologies will be as shown in Figure 1.

The following presentation will give for selected technologies an overview of what could be a technical solution for the requirements and how to integrate them for the benefit of a high mission effectiveness of a future heavy transport helicopter.

1. AIRFRAME LAYOUT AND COMPOSITE TECHNOLOGIES

1.1 Airframe layout and basic composite approach

As mentioned, mission effectiveness is one of the major objectives for future helicopters. This has to be a driver for technologies applied in the airframe. Due to the world wide operation (climate and corrosion), the high static and dynamic loads and the beneficial life cycle costs a composite fuselage is selected in this case study.

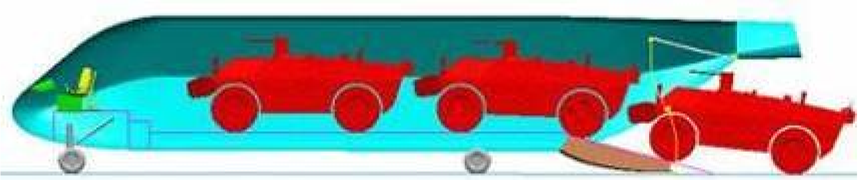


Figure 2: Loading simulation

The airframe layout is based on the loads to be carried inside the cabin and the helicopter configuration selected; in this case the conventional version with main and tail rotor.

To define the inner dimensions of the cabin, loading simulations, see Figure 2, with different vehicles have to be carried out, having done a preliminary sizing of the major load carrying frames. In addition it has been decided to have a “diamond shaped” outer contour. These inputs and the knowledge gained in the NH90 program lead to the general design of the frames, as shown in Figure 3.

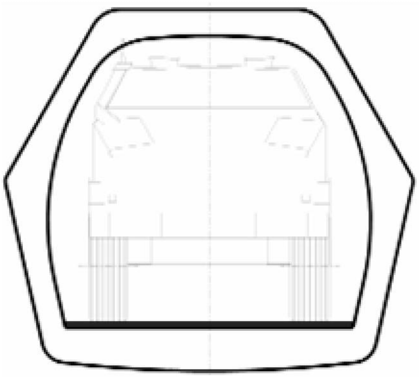


Figure 3: General frame design

Knowing also the position of the major components like gear boxes, engines and landing gear, the load carrying frames can be placed at the right station. With the experience of NH90 one selected for this first approach a frame spacing of about 800mm which is a good compromise for the number of frames and their dimensions. The thicknesses of webs and flanges would be in an acceptable range, which would allow to produce the parts, as a fall back solution, in the conventional prepreg technology, although the aim is to apply latest composite technologies for the airframe. To make production easier and the number of identical parts higher, only three types of frames (Figure 4) have been defined, depending on the loads to be carried. Segmenting the huge frames in an intelligent way is supporting an easy production, integration and repair.

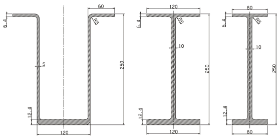


Figure 4: Frame types

The lower part of the fuselage, which will have some quite big bottom flaps for sling load and hoist operations, is designed to provide high crash worthiness. For this reason frames will have two functions: carrying load and providing energy absorption. Regarding stiffness and weight requirements the skin of the fuselage will be a sandwich construction in its baseline version due to knowledge available. A stiffened monolithic solution is being investigated to propose the best weight and cost efficient design. Finally one has to look at the integration of all the individual components/modules for the airframe (Figure 5). Integration is depending on the applied technology.

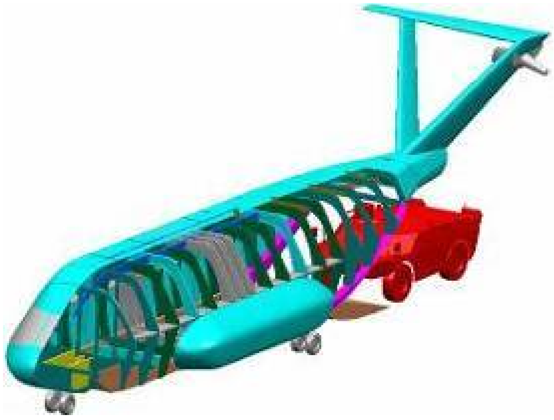


Figure 5: Integrated airframe

Up to now many "individual" components like frames and sandwich panels are joined to get bigger modules. Producing big, highly integrated modules, similar to what is being done for the modern aircrafts like A350 and B787, is the challenge for the next generation of big helicopter airframes. These modules will be defined according to its function and its size. It has to fulfill two functions. The first is to avoid as much as possible complex mating tools and the second to allow a replacement in case of major repair.

1.2 Specific composite technologies – Focus: Dry Fiber Architectures (Preforms)

Future Heavy Transport Helicopter (HTH) concepts will be based on advanced composite technologies, which have to lower production costs compared to today's technologies (Figure 6). Low cost production technologies are the key factor, when up-scaling for a future HTH specification in terms of part size or increasing load carrying capabilities.

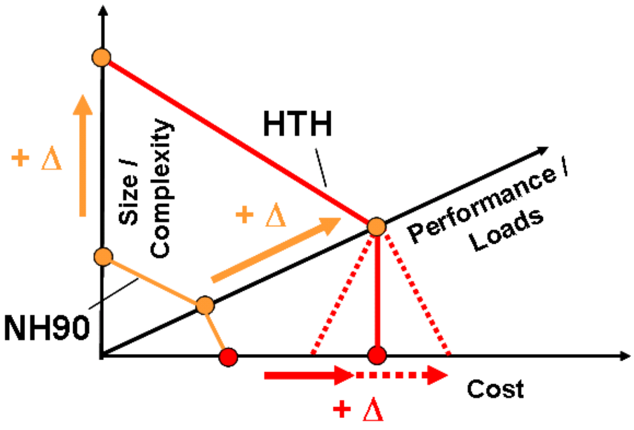


Figure 6: Interrelations between performance, load requirements, size, complexity and production costs

The experience gathered with the manufacturing of NH90 and Tiger parts – mainly prepreg hand-lay-up technologies supported with overhead laser-projections and autoclave curing – is the benchmark. Existing Out-of-autoclave infusion technologies, e.g. RTM, VAP, VARTM etc., will have to improve the current manufacturing process in terms of cost, design freedom and performance. Further advancements in preform technologies (manufacturing of the dry fibre architecture) will play an important role for the selection of future production routines.

Regarding complexity and size, as well as required performance and load carrying capabilities, HTH will exceed NH90 specifications. On the other hand, however, the today's technologies – with individual prepreg ply hand-lay-up – are not up-scaleable easily without increasing cost or production risk. Especially the latter point is the crucial one, since the added value and production time involved in large structures lead to an increased risk of cost intensive rework or scrap rate in production in case of layup/manufacturing errors.

As a consequence, highly reproducible and automatable composite production technologies have to be developed in order to minimize this overall risk. An on-line quality control technology for the step-wise control of part generation is mandatory.

Labor cost is a significant factor in helicopter production; hence it is clear that automation will play an important role. However, a main focus has to be set also on the flexibility of such technologies, since a large range of different parts have to be addressed for HTH (frames, skins, assemblies, etc.).

To automate composite technologies (here: generation of the fiber architecture - preforming), basic requirements regarding the material and process selection are identified. New material families have to be developed in order to reach technological maturity in due time.

As a first approach, automated manufacturing of dry preforms can be considered. For this process it is mandatory to find and to develop semi-finished products, which are capable of being draped as multi-stacks at room temperature to avoid costly and time consuming heating and bindering cycles.

Specially designed seams and stitches, with special thread materials have been developed to match with these requirements. Different process chain studies (Figure 7) have shown, that the preform stitching routine, in-plane preparation of preforms combined with draping and 3D-assembly processes can resolve the problem of automation while staying within a flexible production environment.

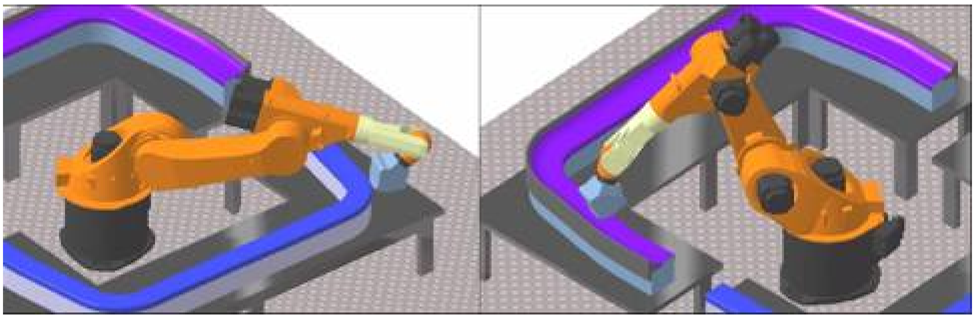


Figure 7: Study of a flexible production cell for future atomated frame manufacturing

This multi-stack dry draping (2D to 3D operation) approach is a key element to save production/labor cost compared to single prepreg ply draping. The draping process has to be designed in a way to prevent cuttings. If cuts would be needed, staggering and overlaps would have to be introduced again and the cost reduction potential compared to standard prepreg lay up processes is lowered. Following the process chain of dry preforming, different dry-assembly steps (3D) will follow the multi-stack room temperature draping. For this assembly process, again preform stitching or bonding operations are being developed. First results show applicability and proof the cost saving potential.

The unidirectional reinforcements needed in highly loaded and curved areas also require special technologies in order to be used in future helicopter programs. Looking at dry fiber materials, “unidirectional” woven fabrics or tapes have to be developed which can be automatically placed (Figure 8) to generate the desired fibre architecture. These materials need to be adaptive to the performing process chain described before. The equipments needed for complex helicopter structures are tested today with different development partners.

A fully dry process based on stitching technology is followed in parallel to a binder-activation technique. Especially an easy binder activation routine offers additional automation potential. However, the flexibility of such processes for different types of parts has to be assessed. In addition, the materials themselves need to be adaptive for high complex shapes. A transfer from aircraft (AC) unidirectional binder materials is not easily possible, since the shape complexity of a helicopter airframe exceeds fixed wing structures.

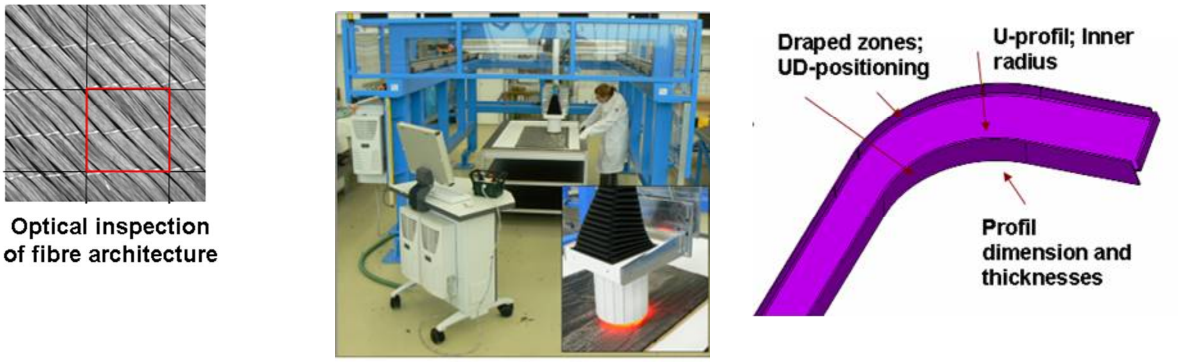
Figure 8: Fibre placement study for fully automated lay-up generation

Figure 9: Multi-ply “one-step” draped

In order to investigate dry preform lay-up technologies, different studies have been carried at Eurocopter. E.g., a frame structure of the NH90 upper-deck has been designed applying the multi-stack draping process (Figure 9). The preform was impregnated and cured applying a special infusion and oven curing process. The results gave confidence in the process (Figure 10). Compaction or infiltration problems have not been found. The static tests performed are very promising in terms of future optimization potentials – no cuttings of fibers in highly loaded part sections. No cut through fibers lead to optimized stress and load transfer. As a consequence load carrying capacities rise – one key item for future HTH structure optimization. The cost saving potential could be shown and especially the potential for further cost reductions is demonstrated as another important factor for an economically producible HTH composite airframe.

Figure 10: Impregnated curved L-Z-frame

On-line process control techniques are addressed in several projects today. One major milestone has been achieved with the introduction of a surface scanning technology combined with specific analysis software. This software allows the inspection of fiber architectures with respect to fiber angles, distortion, seam position and foreign objects in-line the process chain. This basic processing element will be developed further to inspect 3D-aspects of preforms (Figure 11). A calibration of the on-line process control elements is done with experimental scanning equipment. An industrial implementation plan is already scheduled.



Optical inspection of fibre architecture

Experimental Equipment for Qualification

Figure 11: On-line process control elements; Image analysis; Image acquisition; 3D-challenge

2. ACTIVE FLY-BY-X FLIGHT CONTROLS AND ADVANCED AFCS FEATURES

2.1 Motivation

The main reason for introducing active fly-by-x flight controls is the ability to increase the performance of both the aircraft and the pilot. Together with the advanced automatic flight control system (AFCS) the mission performance can by this way significantly be enhanced [9].

In contrast to a conventional mechanical flight control the fly-by-x system can not only provide a complete decoupling of the rotorcraft control reaction but can provide the desired level 1 handling quality by means of applying model following control [8]. By this way the reaction of the rotorcraft can be tailored within the bounds of the physical feasibility to the desire of the pilots. This includes limit protection features and suppression of limit cycles induced or assisted by the pilot, the AFCS and the rotorcraft hardware (e.g. drive-train). The model to be followed can be mission and flight state dependent.

Ancient flight controls did provide a force feedback from the aerodynamic control surfaces to the pilot. Today the high force amplification or even fly-by-x prevents a backward force transmission. However, the force feedback can be reintroduced by active flight controls, which have the ability of changing the force deflection characteristics depending on external parameters. These parameters are not restricted to aerodynamic surfaces, but can include any characteristic of interest. Flight state, limits, warnings etc. can be transmitted to the pilot without the need to change the visual focus to a dedicated display. Thus, the overall workload reduces and the mission effectiveness increases [9].

When landing in an area where small particles could be dispersed by the rotor downwash, the external vision of the pilot could be completely lost (e.g. brown-/white-out). With no visual cues for lateral information, the helicopter will translate sideward and eventually crash into obstacles. Motivated by this problem, the AFCS shall provide upper modes for controlling the helicopter ground position and height in hover and the transition to horizontal flight. Comparable upper modes already exist in advanced AFCS (e.g. EC225), however, with a disappearing GPS sensor signal a horizontal drift will be encountered, causing the erraneous behaviour of the AFCS mode. Advanced sensor systems need to be developed for ensuring the functionality of the AFCS. For formation flight and terrain following modes the challenge is similar, as the main problem is to achieve accurate and reliable sensor data.

2.2 Fly-By-X

An increasing number of aircraft is equipped with a fly-by-x control system. The technology can be judged as mature with regard to safety. The high level of safety is achieved by a sufficient high redundant control system with dissimilar hardware and software design. For certification, the proper functionality has to be ensured by comprehensive verification activities [3], which requires a significant amount of time and budget. A big effort is the regression testing, which shall prove that the software functionality is not inadvertently affected by later required changes.

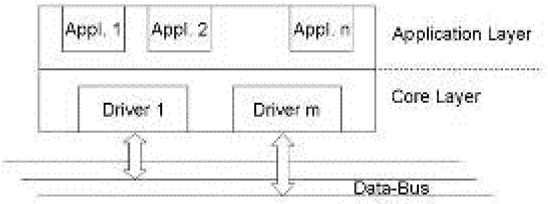


Figure 12: Layered architecture due to partitioning

For reducing the development costs of safety-critical software the aim is to achieve portability and reusability of software applications, to provide modularity of the operating system and the ability to integrate software of multiple criticalities on one hardware unit. This shall be achieved by software partitioning [6] as referenced in the standards DO-178B and ARINC 653. This aspects lead to a layered architecture as depicted in Figure 12.

The safety requirements demand a redundant hardware architecture. Past experience with such architectures has shown that the redundant computer channels shall be synchronized with respect to a global cycle time in order to prevent inhomogeneous system modes and data inconsistency, especially in case of redundancy degradation or multiple failure combinations. This

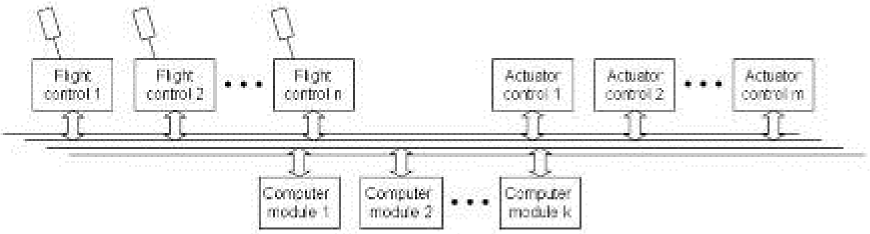


Figure 13: Fly-By-X architecture

can be achieved by implementing a time triggered protocol (TTP) for the signal communication between the redundant instances. As one bus will not be sufficient with respect to safety, multiple TTP busses need to be implemented. Figure 13 sketches the fly-by-x architecture.

Data transmission by fiber optics has the advantage of electro-magnetic immunity and lower weight. The effect of fiber darkening due to a high radioactive dose can be neglected or at least reduced if fiber lengths of less than 50m [7], a pure silica core fiber [2] and wavelengths in the infra red spectrum are used. The need for transforming the optical information into an electronic servo control requires a more sophisticated actuator control electronic, which has to be protected against harsh environmental conditions (e.g. if in a fire zone).

In order to be safe against common mode failures a hardware dissimilar bus technology should be pursued, i.e. both optical and electrical data communication should be used in parallel.

2.3 Active Flight Controls

Definition: *Active controls show a high bandwidth of force feedback, which can be modified in a big extent in real-time by the pilot and the flight control computer.*

The biggest benefit of variable tactile feedback is expected in the collective and cyclic control axis. Thus, active inceptors should be introduced in those axes. The yaw-control could be kept passive if the pilot will not require tactile information about the yaw-limitations eventually done by the FCC. The cyclic center stick is replaced by a side stick on the right hand side of the pilot, the collective lever is replaced by a sidestick similar to the cyclic stick, but limited to one degree of freedom. If the yaw control input is assigned to the lateral direction of the left hand sidestick the pedal components could be removed. This would ease the ergonomic adjustments, as the feet no longer need to be considered and, further, would allow to double the number of similar active units, which would ease logistics and reduce the LRU price. A safety analysis needs to clarify, if the brake controls can also be moved to the active sidesticks, or if a separate control remains necessary. The fact that the pilots left hand can not be used for other tasks during yaw control inputs and the requirement of minimum additional pilot training might prohibit this control assignment. However, simulator and flight tests shall clarify the applicability.

Mainly soft- and hard-stops will be used for the transmission of tactile information. They can inform the pilot about the direction in which limits should not be exceeded. Soft-stops can be pushed through if required. The force necessary would be proportional to the negative resulting effect. Even though a hard-stop has an infinite programmed push through limit, at the end, the final limit is defined by the motor. Even though the pilot might be able to push-through a hard-stop, the FCS would limit the hard-stop exceedance. Vibration cues do not provide directional information and could just be used as an attention getter. However, they are probably more disturbing than helping the pilot. Global and position dependent damping can improve the stick handling significantly [5]. Friction is not adequate for tactile cues transmission, but is required for hands-off operation (e.g. collective axis).

As a general rule the pilots like small forces at the finger reference point and a resolution of the tactile information as high as possible. With both, a low inertia and a high soft-/hard-stop gradient, these wishes can be fulfilled. The maximum achievable tactile quality, however, is limited by the bandwidth of the sidestick. In [4] the optimal cue characteristics for a given sidestick have been determined. These values are accepted by the pilots, but a sidestick of higher tactile quality will provide the potential for further improvements.

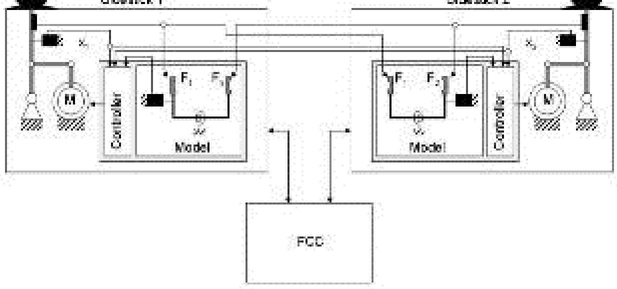


Figure 14: Dual sidestick control

A high bandwidth is also necessary for simulating the mechanical coupling of the pilot and co-pilot primary controls, which has been identified as a must using active controls. The force due to the high stiffness of the simulated mechanical linkage has to be generated by the sidestick motor. Further, the sensor data has to be transferred rapidly. Figure 14 shows the signal paths and the control architecture for being able to change the coupled system characteristics.

The probability of the failure of the active functionality shall be less than 10^{-9}/Fh, i.e. a degradation from active to passive mode is not allowed. The reason for this requirement is that additional training due to degradation is not desired. Further, the lack of synchrony of the pilot and co-pilot controls requires additional measures, which increases the overall complexity.

2.4 AFCS Features

The required sensor signals for the advanced AFCS modes like formation flying, terrain following and autonomous landing could be generated by fusion of rather conventional sensor signals (radar, microwave, laser etc.): Different sensor types, each of which is specialized for different environmental conditions, are combined, such that a highly accurate and reliable sensor signal results.

For the brown-/white-out problem an alternative would be to use the acceleration data from an IRS and mathematically integrate it in order to achieve the required position data. The sensor accuracy defines the time for which the position will stay within a certain range. Thus, for minimizing drift, the integration bias should be reset shortly before the brown-/white-out condition (e.g. by GPS support). If a global navigation signal is not available and the base for sensor fusion is not wide enough, a solution for providing a delta position signal (e.g. for autonomous landing or formation flying) could be an equipment which actively sends position data. For a brown-out scenario, for example, on the landing site such a unit needs to be positioned. It could have been dropped in a fly over or is provided by ground personnel. For formation flying a unit is required on each helicopter, see Figure 15.

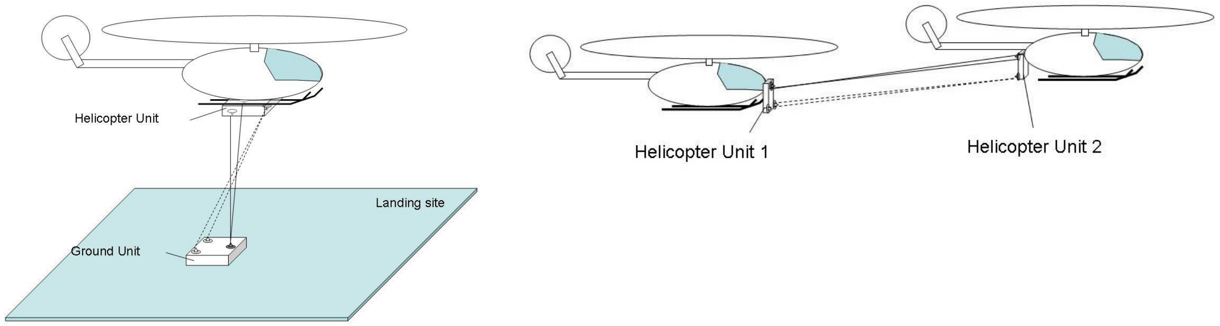


Figure 15: Sensor setup for autonomous landing and for formation flying

3. SITUATIONAL AWARENESS

Situational awareness is a key factor for perfoming the challenging mission tasks of the HTH. It is of utmost importance for the pilot to know every detail about the topography he is flying in, about the planned flight path and actual deviations, about hazardous weather along the flight path, and – of course – about the threat situation. To perform the operation, the pilot should have the optimal support by the latest technology concerning sensors, digital maps, navigation systems, display and presentation technology, as well as planning and problem solving assistance.

3.1 All weather capability

In order to enable operations of the helicopter at almost all meteorological conditions, special mission equipment has to be foreseen. Obstacle awareness (with respect to air traffic as well as ground obstacles) has to be guaranteed and reliable obstacle detection is essential especially for NOE flights. Unfortunately, on the market there is no reliable sensor system available which satisfies those needs unconditionally. Of course, there are Obstacle Warning Systems based on Lasar-Radar technology available, they produce good resolution images but they do not guarantee obstacle recognition at reduced meteorological conditions. Microwave radar systems on the other hand overcome the problem of bad weather conditions, but they need large antennas in order to produce high resolution images.

For HTH the need for high resolution images is questioned. If a detailed 3 dimensional map of the operational area is available and the navigation means are precise enough, this map could be presented to the pilot in a perspective way, replace the direct view out of the window. This type of display became known as “Synthetic vision”. However, this “artificial world” is not safe and reliable enough to allow for helicopter flights without additional obstacle recognition sensors and without adequate guidance symbology for piloting. Based on microwave radar technology for possible warning concepts are conceivable:

Multi-Antenna Array

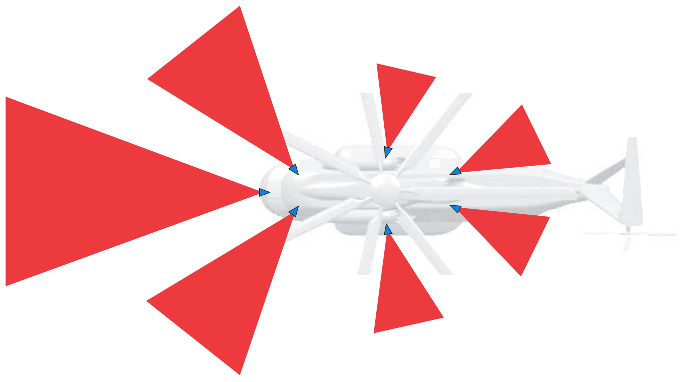


Figure 16: Antenna locations for the Multi-Antenna Array

This approach placed a certain number of small radar antennas around the helicopter, each of them covering and monitoring a different angular section of the 360° surroundings. Depending on the selected radar frequency, power of the transmitter and physical dimensions of the antennas the obstacle situation at a certain radius around the helicopter can be investigated. With adequate selection of the radar frequency even drilled power lines could be recognized. A possible arrangement of the antennas is shown in **Error! Reference source not found.**.

Rotating Synthetic Aperture Radar (ROSAR-OWS)

Based on ROSAR technology an obstacle recognition system could be realized which scans permanently the 360° environment of the helicopter. The antennas could be fixed mounted with the hub cap of the HTH rotating with the rotor and thus allowing for a circular synthetic aperture. Advantage of that kind of radar is the excellent angular resolution in azimuth which

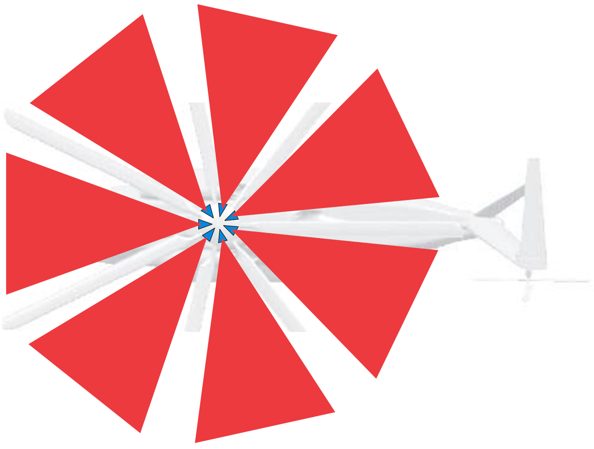


Figure 17: Antenna locations for ROSAR - OWS

could be 1° or even less with the proposed design. The schematic arrangement of the antennas for ROSAR-OWS is given in **Error! Reference source not found.**

3.2 Next generation Pilot supporting systems

Today's cockpits need a multitude of sensor information which is presented to the pilot via numerous different interfaces. At the same time the mission requirements are tougher than ever before. Pilot supporting systems – on which Eurocopter is working since almost a decade – can enable the crew to perform more demanding operations without reducing safety margins: merging and interpretation of information from different sources, automatic conflict resolution capability based on artificial situation awareness inside the avionic systems, and proposals for pilot reactions which are optimal at the current situation.

For HTH a pilot support system is under consideration which provides the pilot or the crew adequate assistance for all mission and flight phases. It shall detect relevant conflicts between the current situation and the pre-determined "desires". Furthermore it shall provide automatic assistance for decision-making in order to keep the workload at an acceptable level.

Figure 18: Man Machine Interface

Of course, the interaction of the Human Machine Interface (see Figure 18)has to be designed for these tasks by:

- enlarging the missin spectrum by providing a 4 axis AFCS
- improving HMI for manual guidance and situation visualisation
- using speech recognition and speech output
- recognition of the pilot's intents and detection of pilot's errors
- taking over – if necessary and convenient – standard tasks such as communication, flight planning, flight preparation and debriefing.

ABRIVATIONS:

AFCS	Automatic Flight Control System
DVC	Degraded Visual Conditions
FCC	Flight Control Computer
GPS	Global Positioning System
HMI	Human Machine Interface
HTH	Heavy Transport Helicopter
IRS	Inertial Reference System
LRU	Line Replaceable System
MTOW	Maximum Take Off Weight
NOE	Nap On Earth
TTP	Time Triggered Protocol

REFERENCES

[1] McKenna, James T., *“Look ahead, airframes”*, Rotor & Wing, May 2007, page 28ff

[2] Berghmans, F.; Brichard, B.; Fernandez, A.F.; Van Uffelen, M.: *“Reliability issues for optical fibre technology in nuclear applications”*, Proceedings of 5th International Conference on Transparent Optical Networks, 29 June-3 July 2003, pp: 252- 257, vol.1

[3] Bickel, N.; Butter, U.; Hammelindl, M.; Eichberger, W.: *“Getting a Primary Fly-By-Light Control System into Flight”*, Proceedings of the 59th American Helicopter Society, USA, Arizona, May 6-8, 2003.

[4] Burgmair, R.; Alford, A.; Mouritsen, S.:*”Definition and Verification of Active Inceptor Requirements for a Future Tiltrotor”*, Proceedings of the 31st European Rotorcraft Forum, Florence, Italy, 2005.

[5] Einthoven, P. G. et al: *“Tactile Cueing Experiments with a Three Axis Sidestick”*, Proceedings of the 57th American Helicopter Society, USA, Washington D.C., May 9-11, 2001

[6] M.F.R. Keuning: *“Software Partitioning for Safety Critical Airborne Systems in Practice”*, 25th European Rotorcraft Forum, Rome, Italy, 14-16 September, 1999

[7] LaBel, K. A.; Marshall, C.J.; Marshall, P.W.; Luers, P.J.; Reed, R.A.; Ott, M.N.; Seidleck, C.M.; Andrucyk, D.J.: *“On the suitability of fiber optic data links in the space radiationenvironment: a historical and scaling technology perspective”*, Aerospace Conference, proceedings., IEEE, 21-28 Mar 1998

[8] Pausder, H.-J.; von Grünhagen, W.: *„ATTHES In-Flight Simulator for Flying Qualities Research”*, European Rotorcraft Forum, 1991

[9] Stiles, L. R.; Mayo, J.; Freisner, A. L.; Landis, K. H.; Kothmann, B. D.: *„’Impossible to Resist’ – The Development of Rotorcraft Fly-By-Wire Technology“*, Proceedings of the 60th American Helicopter Society, USA, Baltimore, MD, June 8-10, 2004