Design, Development and Flight Testing of the new EUROCOPTER EC145 Medium Twin

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Abstract

The EC145 is EUROCOPTER's new medium weight twin engined helicopter, successor of the well proven BK117 model, and destined to match latest market requirements by implementation of state-of-the-art technology into rugged and proven design.

This paper focuses on design requirements and objectives for the EC145, which lead to airframe enlargement and reshaping, introduction of most modern technologies such as new main rotor airfoils, and fully integrated glass cockpit design as well as further system upgrades in order to satisfy operational and economical customer demands.

Market response and reaction promise highest acceptance of the design, which is based on proven high technology items taken from EC135, reliable design features of the former BK117 model, and new development applications, which are all combined in this helicopter.

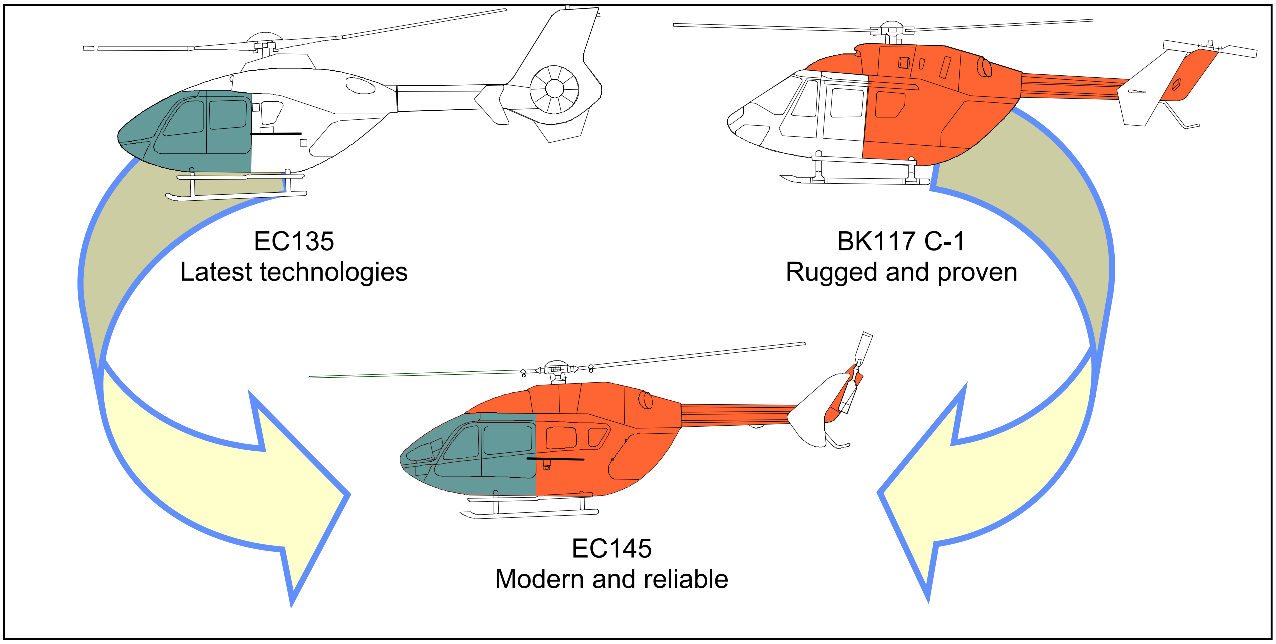
Within this paper, also first test results will be shown, as well as the current development status is given.

Introduction

Beginning with the BO105 helicopter in 1971, and followed a decade later with the BK117, MBB Helicopter Division - now EUROCOPTER Deutschland - brought up two innovative products, which both revolutionized the market by advanced design features. Their characteristics included twin engine application, four-bladed hingeless rotor "System Bölkow", redundant system layout, and rear loading capability together with a one-level cabin and compartment floor for unobstructed cabin use. The BK117 was co-developed with Kawasaki Heavy Industries of Japan, who was responsible mainly for design and manufacturing of the center fuselage, main gear box and electrical system as well as fuel tank design.

In the 90's, further improvements such as glass cockpit technology and aerodynamic optimized fuselage shaping, along with the use of composite material and new production methods - not mentioning other design features (for those see /4/ and /5/) - lead to development of the light twin EC135 as successor to the BO105. As a logical step, the EC145 now follows to satisfy market demands of the new century by taking the best technology available from EC135 and BK117, and providing customers a state-of-the-art-technology

Fig. 1: EC145 Evolution



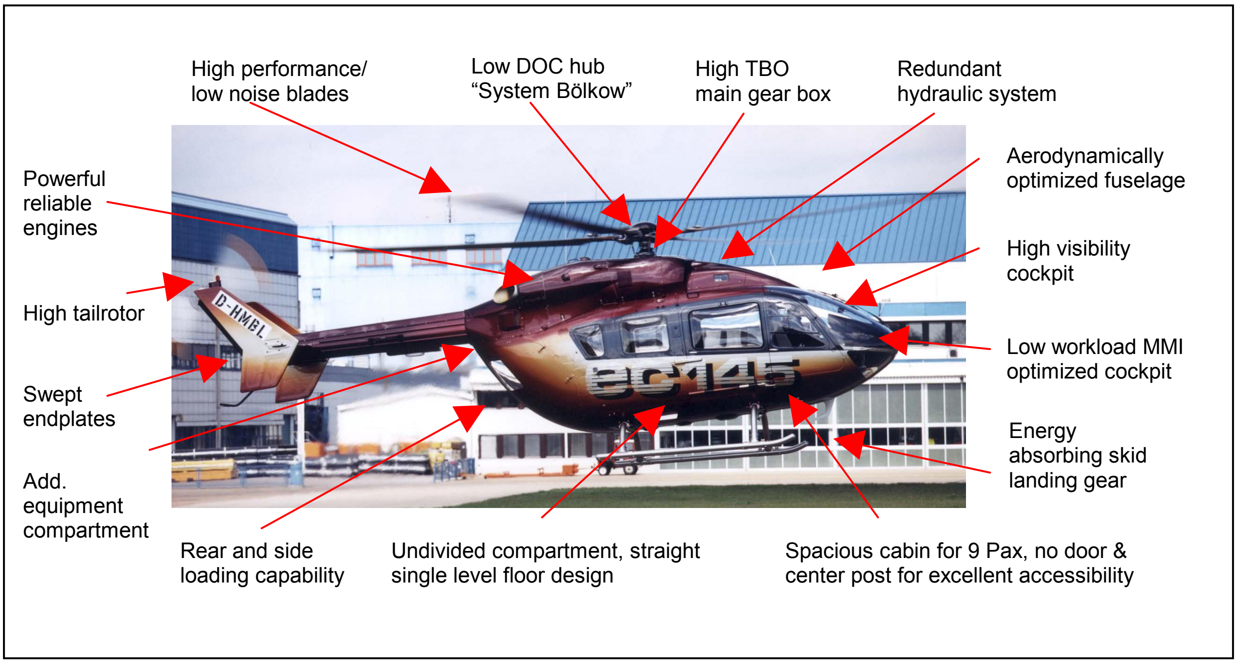


Fig. 2: EC145 Characteristics

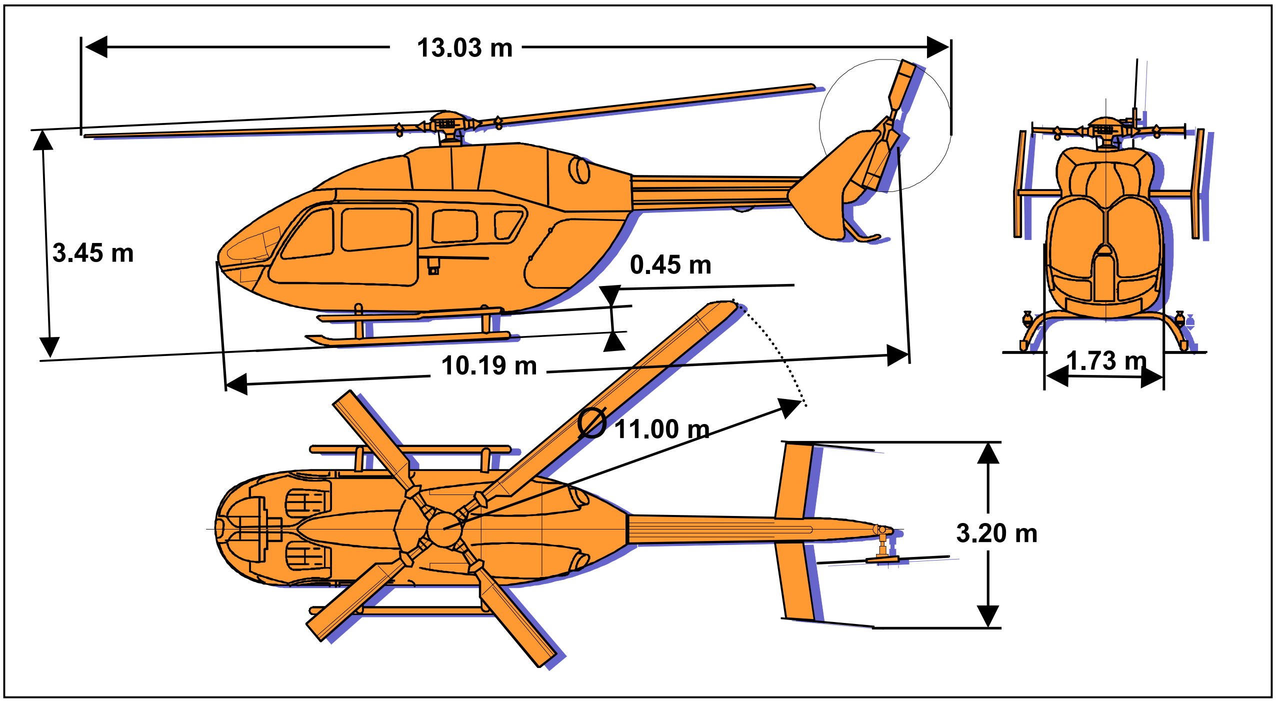
medium twin helicopter meeting their multi-mission requirements for present and future operations. These include mainly rescue and EMS missions, paramilitary/police missions, VIP/passenger transport, cargo transfer, off-shore oil rig support, areal photographing and training. Balancing the various operational requirements called for increase of payload, improved range, reduced noise signature, eased cockpit crew workload, comfortable cabin access and size enhancement and flexibility, system reliability and safety, as well as competitive operating costs. Last, and known from the BK117, also performance Class 1 requirements were to be met to allow operation under JAR Ops 3 rule.

Main Helicopter Design Characteristica

Latest design tools allowed a straight forward, efficient and fast design process. Use of 3-D CATIA allowed creating a Digital Mockup for first fuselage investigation on e.g. tank installation and cabin shaping, and further on for "installation" of optional equipment in a very early design phase. Design commonality with the EC135 offered the possibility for reduction of specific assembly tooling. Use of improved material allowed low weight components and manufacturing cost reduction.

The primary fuselage structure is mainly of sheet metal design, while other major parts such as the cockpit frame, roof, floor, engine cowlings and doors are made of weight reducing composite material. Figure 1 simplifies the

Fig. 3: External Dimensions



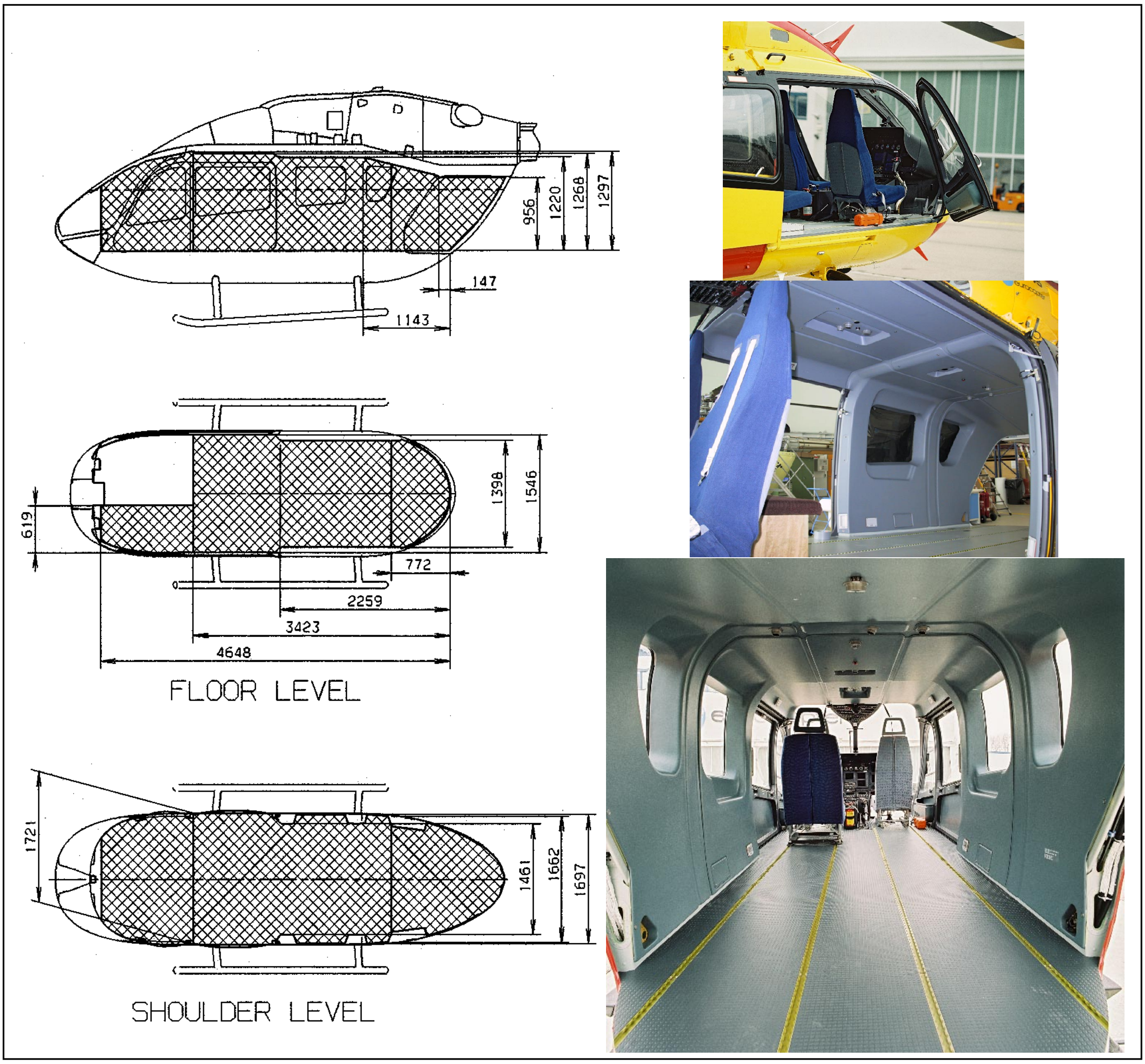


Fig. 4: Cabin Dimensions and Versatility

evolution of the EC145: the cockpit structure design is taken from the EC135, while fuselage and empennage design are known from the BK117 C-1.

Fuselage

The EC145 fuselage was lengthened by 200mm, and was widened by 180mm to accomodate two additional passengers in a third pax row. Alternatively, e.g. for casualty evacuation, the cabin layout offers space for max. two pilots plus two litters plus three crew seats for doctor and attendant. The overall cabin volume increased from 5m^3 to 5.85m^3, see also Figure 4.

The center post was removed, as well as the door post could be renounced, both features improving access to the cabin and enhancing visibility, thus contributing to safety during certain flight operations such as rescue winching. Flight controls including primary systems are now routed through the windshield middle post, and have been realized for the first time by the use of flexball technique.
The aerodynamic optimized front area of the cockpit structure contributes to the modern design. The tail boom and tail rotor were taken from the BK117 C-1, whereas some changes were applied by sweeping back the horizontal stabilizer, changing its size and re-shaping the endplates. All this for improved helicopter dynamic response and protection against inadvertent contact with the turning tail rotor.
Crash resistance was one of the mandatory requirements, which have been incorporated in the fuselage design incl. fuel tank, landing gear as well as pilot/pax seats.

Main Rotor Blade

The main rotor blade design requirements included a 150kg thrust increase at comparable power versus BK117 C-1, noise reducing blade shape in

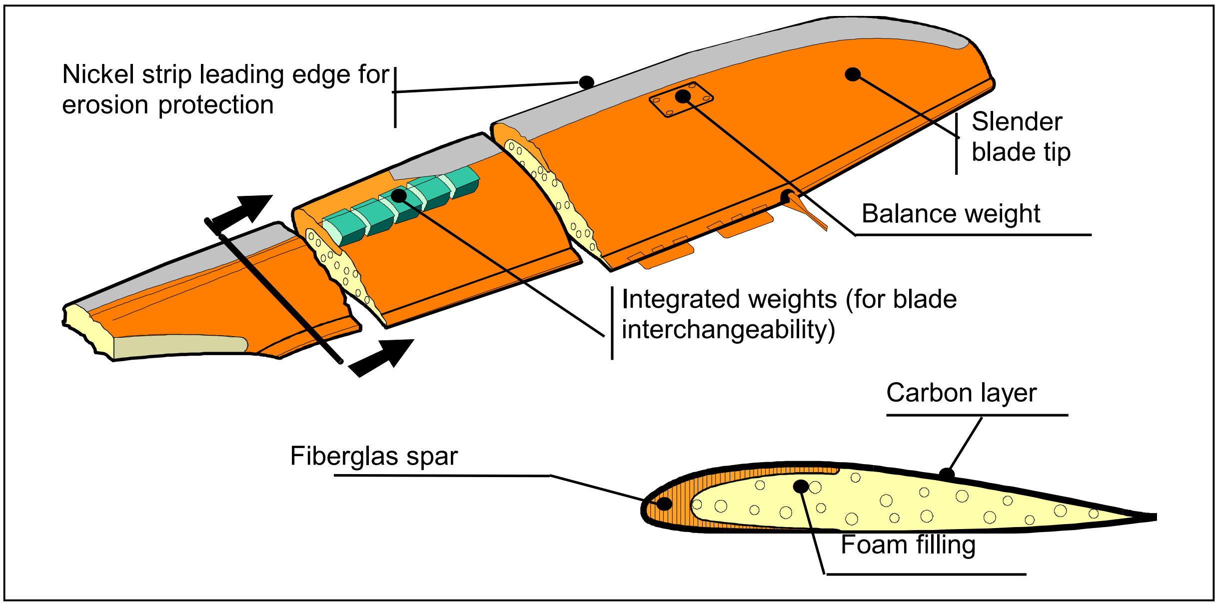


Fig. 5: Advanced Technology Main Rotor Blade

particular of the slendered tip section, Nickel leading edge design for erosion protection, integration of balancing weights to allow blade interchangeability, and the use of advanced production methods, see Figure 5.

The new main rotor was developed /1/ and flight tested /3/ in the framework of the ATR (Advanced Technology Rotor) research programme. The rotor layout was achieved as the result of an evolutionary process. A newly developed series of advanced blade airfoils with optimised distribution over the blade radius was applied. The blade planform with negative taper and the twist distribution were based on the experience gained in former research programmes, see Figure 6.

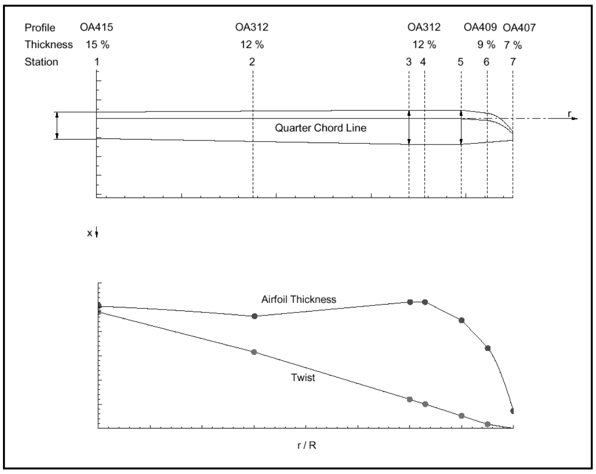


Fig. 6: ATR Blade Geometry and Twist

<u>Cockpit</u>

In order to allow the pilot concentrating on his mission tasks, the cockpit instrument panel has been simplified, and has been ergonomically adapted from the EC135. It offers the basic Central Panel Display System (CPDS), as well as the optional MEGHAS Flight Control Display System (FCDS), both of LCD technology and developed by Thales. This glass cockpit is also common to further EUROCOPTER helicopters such as the EC120, EC130 and EC155.
The central warning unit gives visual as well as aural signals, which are triggered e.g. by engine fire detection or out-of-normal-operation rotor RPM. Besides of the back-up conventional instruments clock, air speed indicator, stand-by-horizon, altimeter and triple tachometer, the central instrument panel includes the main switch panel for engine start, VARTOMS (Variable Rotor RPM and Torque Matching System) control panel and DC power control.

The Central Panel Display System CPDS is composed of the VEMD (Vehicle and Engine Monitoring Display) and the CAD (Caution and Advisory Display).
The VEMD is a duplex indicator composed of two active matrix liquid crystal displays. The CAD is a simplex indicator of one active matrix liquid crystal display. The CPDS displays all necessary engine and vehicle parameters, such as:

- The FLI (First Limit Indication) ΔN1, N1, TOT and TRQ
- Fuel Indication
- Display of Cautions and Advisories
- Vne
- Pressure and Temperature of Engine Oil
- Bleed Valve status
- Pressure and Temperature of Main Gear Box Oil

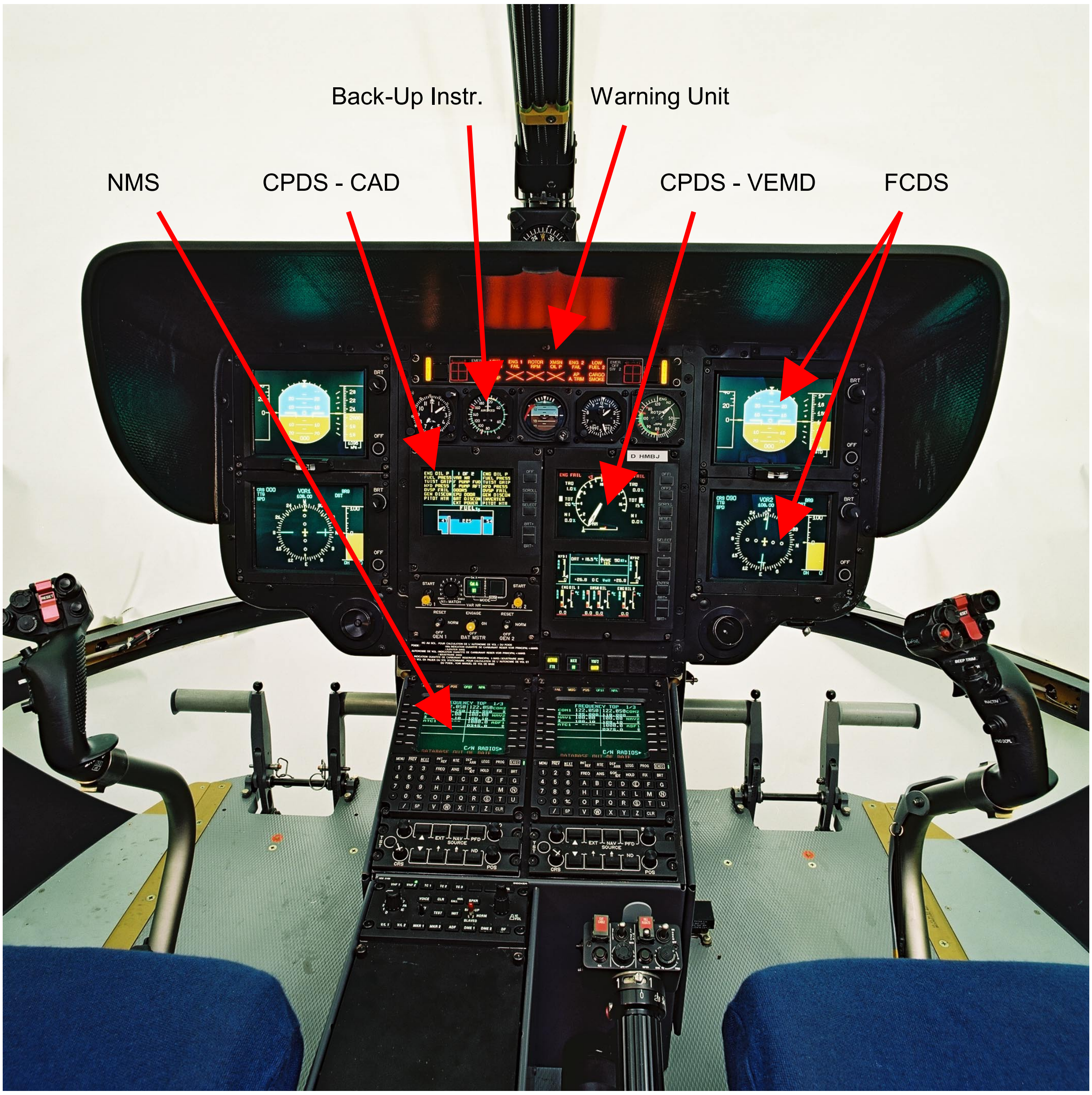
- Mast Moment
- Hydraulic Pressure
- Ouside Air Temperature OAT
- Fuel Flow and remaining Flight Time (optional, if installed)
- Electrical System parameters
- Icing Rate (optional, if installed)
- Hook Load / Rescue Hoist Cable Length (optional, if installed)
- Flight Duration

and performs the following complementary functions:

- Engine parameter consistency check
- Mast Moment overlimit recording
- CPDS and associated sensors maintenance
- Vne overlimit warning
- Engine Starter reset (in case of OAT > -30°C)

The compact, but clearly arranged and easy understandable instruments, along with the large glazed cockpit window offer MMI optimized operation with reduced workload and provide superior visibility to the outside terrain, thus significantly increasing safety in particular at flight near ground and in obstructed area.
Maintenance functions included in the display system furthermore reduce operating costs. The digital system allows easy transfer of air data computer and attitude/heading reference signals to the AFCS and to other equipment such as digital maps. Displaying video pictures such as received from Weather Radar or FLIR system is possible as well, and NVG compatibility allows special operations such as e.g. police missions or drug control.
The optional Flight Control Display System is composed of two LCD displays, one for showing primary flight informations incl. attitude/airspeed/ altitude/vertical speed and AFCS status, the other displaying navigation information.

Fig. 7: State-Of-The-Art Cockpit



Low Noise Design

Exterior noise is still one of the most critical aspects for the public acceptance of helicopters. Due to the increasing sound exposure in communities, the environmental noise limits specified by certification authorities and the local regulations at the operating site are constantly becoming more stringent.
The reduction of the exterior noise emission was therefore a major objective for the development of the EC145 helicopter. To achieve this goal, a new optimised main rotor blade - see above - and a redefined rotor rotational speed law were applied to the EC145.

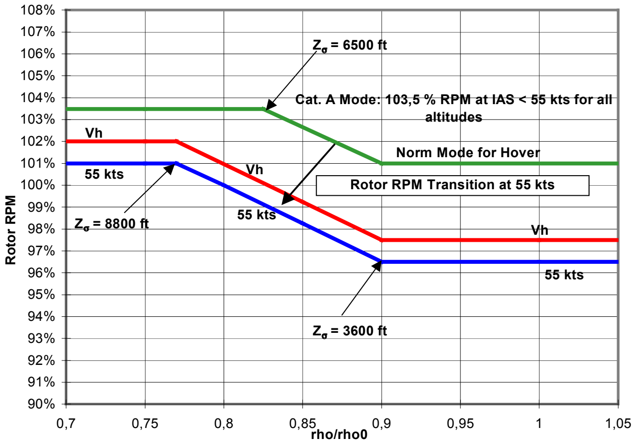


Fig. 8: VARTOMS Control Law

Rotor RPM follows the law as shown in Fig. 8. High RPM at low airspeeds allows safety margin for controllability and increases performance during hover missions. Low RPM is automatically commanded during takeoff and landing, thus contributing to the low noise emission profile. At airspeeds above 55kt , RPM is then slightly increasing. The entire RPM niveau is dependent of altitude and temperature. When operating within a density altitude band of 3600ft to 8800ft, altitude and temperature sensors command a rotor RPM, which increases with decreasing density, thus counteracting the effects of air density and offering more performance and better controllability. This kind of RPM control by the VARTOMS system is already known from the BK117 C-1 helicopter, and has been adapted and optimised for the EC145 in particular under noise aspects.

One of the most important aeroacoustic parameters is the rotor rotational speed. In most flight conditions (tip mach numbers M<0.80) the main rotor noise is dominated by the blade loading noise, which follows the 6^{th} to 7^{th} power of the tip speed. Due to the fact that the change of the rotational speed will affect other rotor parameters, an efficient noise reduction approach considers not only tip speed but also design parameters like disk loading and solidity. For the EC145 main rotor, the reduction of tip speed is supported by an increase of blade chord in order to effectively minimise the noise emission. Based on the experience of the low noise design applied to the EC135 main rotor a similar variable rotational speed law was therefore adopted for the EC145.

Another design parameter which is taken into account is the airfoil thickness. The EC145 rotor has a decreasing profile thickness in the tip region. This leads to a reduction of the thickness noise and is favourable to avoid shocks and transsonic flow regimes which are responsible for the annoying high speed impulsive noise.

A further method to reduce sound emission (especially for high speed flight) is the use of advanced airfoils, in order to reduce drag mach divergence number and to improve the transsonic characteristics. For the EC145 main rotor this was realised by applying a distribution of airfoils of the OA4 family which are optimised with respect to high lift-to-drag ratio, and the OA312 airfoil (see Figure 6, above).
The improvement in main rotor noise emission due to dedicated blade tip designs could be measured in wind tunnel tests and was also proven in noise certification measurements. In order to investigate the potential of tip shape design as a passive means for noise reduction, 4 different blade tip designs were tested within the ATR programme (Ref. /1/). Once again the parabolic blade tip (as on the EC135 helicopter) allowed for the highest noise reductions, especially in the critical descent (Blade Vortex Interaction noise) and high-speed (High Speed Impulsive noise) flight regimes. This blade tip was therefore adopted for the EC145 main rotor.

The noise certification measurements for the EC145 were conducted in accordance with the ICAO Annex 16, Chapter 8 and FAR PART 36, Appendix H standards. Noise measurements include three different flight procedures: flyover, takeoff and approach (ref. /2/). The time integrated Effective Perceived Noise Levels (EPNL) used for the noise certification are derived form acoustic pressure time histories measured by using three microphones (one below and two with a lateral distance of 150 m to the flight path of the helicopter). The noise certification levels of the EC145 measured in accordance to the regulations are summarised Table 1.

The achieved significant margin of nearly 7dB is beneficial for all customers operating in noise sensitive areas, even under more stringent noise limitations already under discussion for the near future.

General Data	
Min. T/O weight	1750kg
Max. T/O weight	3550 kg
Sling Load	1500kg
Seat capacity	1 pilot + 9 pax
Main Rotor	
Diameter	11.00 m
Number of blades	4
Airfoils	OA415, OA312, OA409, OA407
Chord	0.325 m (Average)
Planform	Negative Taper
Twist	-12° linear
RPM (at 100 %)	383.36 (U=220.8m/s)
Tail Rotor	
Diameter:	1.956 m
Number of blades	2
Airfoils	MBB-S102E
Chord	0.22 m
Planform	Rectangular
Twist	-10° linear
RPM (at 100 %)	2169.3

Table 1: Technical Data of the EC145

Performance and Cost

One of the EC145 design goals was to improve the cost of performance. Achieving this was realised by

- aerodynamic reshaping of the front fuselage/ cockpit section,
- enlarging the center fuselage to allow a spacious cabin, and integrate an enlarged fuel tank system below the floor,
- combine all this with high performance main rotor blade design, and
- use of reliable and proven systems, including high value items engine, rotor hub and main gear box

thus offering an increase of the max. take-off weight and payload, an increase of the range, and voluminous cabin space for cargo and/or passengers, at known system maintenance cost.

The cost per flight hour is the sum of a certain number of factors, which depend not only on the manufacturer but also on the operator and the missions carried out by the aircraft. The estimate of the technical costs bearing in mind the average consumption of spares and the provisions for replacing, overhauling , repairing or exchanging life limited parts, the Direct Maintenance Costs value is expected to be very close to the known cost of its predecessor, the BK117 C-1.
DMC are estimated to be at around €270.

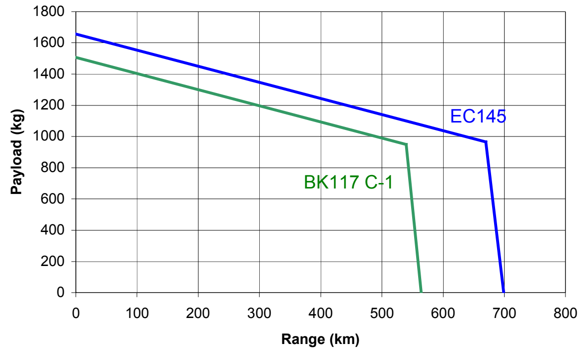


Fig. 9: Payload/Range at Economical Cruise Speed

Flight Characteristics

Already during early flight testing of the new main rotor blade it was evaluated, that the EC145 inherited its high maneuverability characteristics from the BK117 with the same hingeless hub "System Bölkow". Furthermore the helicopter's controllability was very well appreciated by the test crew, and satisfactory control margins were substantiated in all flight conditions also at high-g-maneuvers, as well as in quartering flight/in hover under side-/rearward wind conditions even beyond 30kt.

The advanced architecture of the main rotor blade including modern profiles leads to an appreciated extension of the handling quality limit.
The high g-capability of the rotor also allows higher loading as well in high speed flight as in turns and instationary manoeuvers.

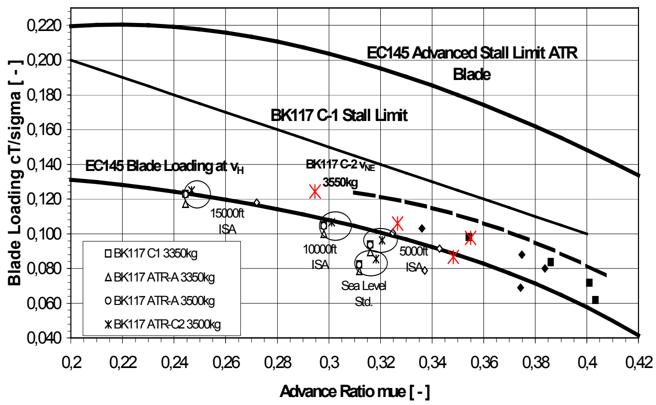


Fig. 10: Blade Loading at Vh in comparison to Stall Limit

Vibrational Characteristics

As shown in Figure 11, the observed vibration level in level flight up to Vh is as expected below 0,1g. Flight comfort is rated pleasant and suitable to the kinds of missions, for which this multipurpose helicopter is designed for.

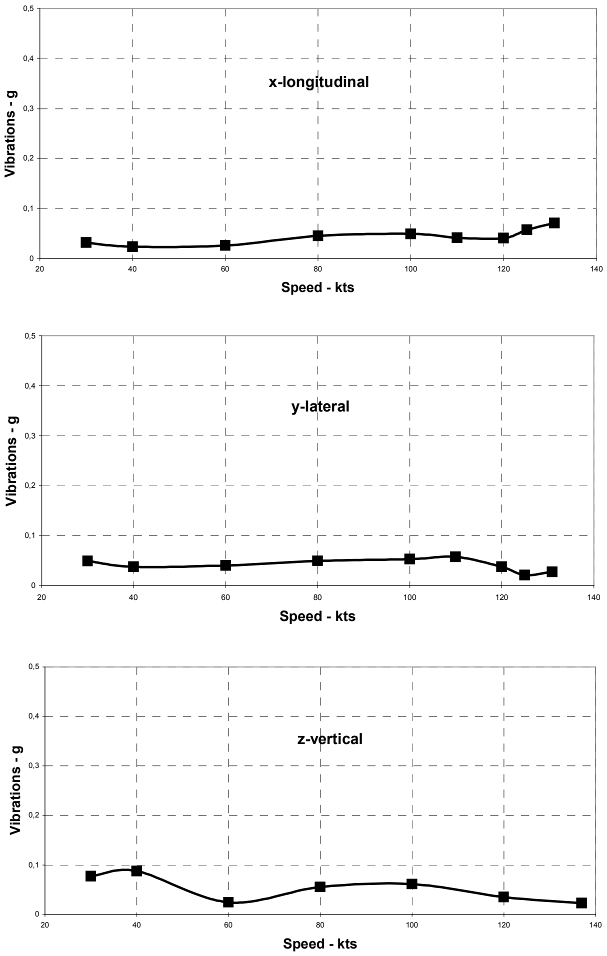


Fig. 11: Low Vibration Levels

Further System Design Features

The EC145 design is characterized by further valuable design features, such as

- three axis duplex main rotor actaution system of high reliability, easy maintainability and low weight,
- flexball controls in all four axis to allow for center post removal and space saving routing within the fuselage,
- semi-automatic engine start-up procedure to reduce pilot's workload,
- efficient bleed air heating system, and
- high TBO main gear box

Whereas most systems are known from the BK117 and EC135, the minority of systems such as the semi automatic start-up device via the collective stick's twist grip, and the bleed air heating system were newly designed. Reliability and serviceability was thereby mated to an optimum.

Customization

In order so satisfy most customer requirements from the beginning on, a variety of different optional equipments is presently under development for delivery already with the first helicopter:

- Avionique Nouvelle (Thales) glass-cockpit with digital avionics system
- Duplex Automatic Flight Control System (Autopilot) for SPIFR operation, with Flight Director
- Cockpit Voice Flight Data Recorder & UMS
- Rescue Hoist, installation LH & RH
- Emergency Floatation System, compatible with snow skids, see Figure 12 below:

- Wire Strike Protection System
- Cargo Hook, and mirror
- Weather Radar, multi-mode search and rescue
- Internal auxiliary Long Range Fuel Tank
- SX-16 Nightsun, with IR-filter, on multifunction step
- Sandfilter system
- Settling Protectors, Snow Skids
- YAW Stability Augmentation System
- NVG compatible cockpit

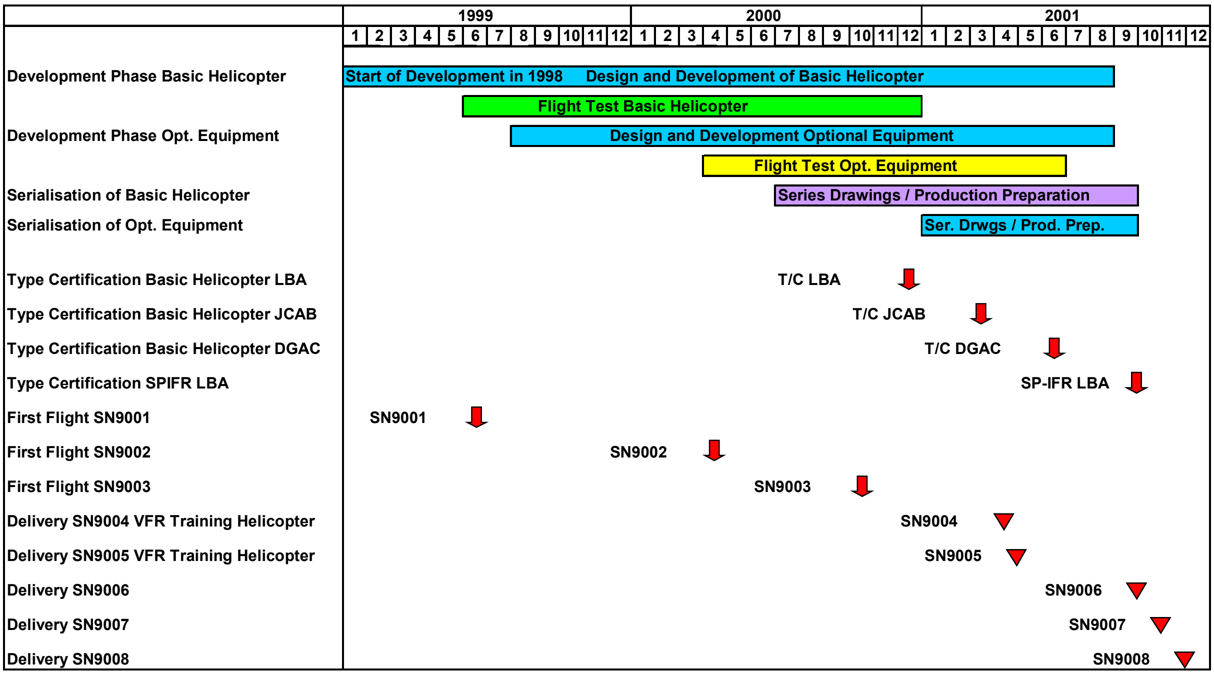


Fig. 13: EC145 Development Schedule

In order to minimize design effort and to shorten the required development time, see Figure 13, parts commonality to existing EC135 as well as BK117 C-1 optionals was a major principle.

Start of the EC145 development and design phase was in 1998, which lead to a first flight in June 1999. During this first flight with a duration of 90 minutes, a velocity of 130kt and an altitude of 10000ft could be reached. This aircraft SN9001 was dedicated to flight test the basic vehicle. It was joint in March 2000 by the first flight of the Kawasaki operated test helicopter, in April 2000 by the second ECD helicopter SN9002 dedicated for flight test of optional equipment, and thereafter supported by the helicopter SN9003 from October 2000 onwards. This last helicopter was purely dedicated to perform flight tests for the duplex autopilot system. In total, four helicopters are in use to accomplish all test activities for basic vehicle as well as optional equipment development and certification, in order to ensure delivery of fully equipped customer aircraft starting from September 2001 onwards.
LBA Type Certificate of the basic helicopter was granted in December 2000 just 18 months after first flight of SN9001. This was followed by basic T/C with JCAB in Japan during March 2001, and basic T/C with DGAC of France in June 2001.
First customer aircraft have already been delivered in a VFR configuration during May 2001 in order to establish crew training and allow for a smooth transition for the customer to the new aircraft EC145.

Summary

A wide range of new technology was combined with proven hardware, forming a new medium twin helicopter for the new century.
High performance main rotor blades, an aerodynamic optimised fuselage, a low workload cockpit with state-of-the-art MMI design features, high visibility cockpit frame/window design and an voluminous cabin with large floor and access area are the major design characteristica of the EC145. The technological features and overall attractive outside and inside appearance, along with the visual and aural/low noise attributes have proven in flight and during market presentation, such that this helicopter is expected to follow the successfull BK117. First customer response is highly positive, and market acceptance of the design is foreseen also for the cost of its performance, its versatility, its space, and its seating capacity.
IFR capability as well as class 1 performance are given, and allow this new helicopter to operate under a wide range of conditions incl. JAR OPS3.
Having finalised the basic EC145 design and certified a variety of optional equipment, this product is well prepared for the market requirements of the coming years.

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