

The TIGER Attack Helicopter: Technical / Program achievements and perspectives

Authors: Antoine Lheureux, Gérard Cuadrado, Marc Jouan
Eurocopter – Marignane, France

Abstract

The TIGER attack helicopter, developed by Eurocopter in several versions, is an example of helicopter developed from “blank page” strictly in accordance with the operational requirements, without the constraints of using existing modules or functions. This paper describes the operational context, the related technical requirements and the design solutions. The very constraining requirements led to innovative solutions in many aspects: composite airframe, low weight and high life time Main Gear Box, supercritical rear transmissions, hingeless rotor, Hands On Controls and Sticks concept for Human – Machine Interface, redundant avionics with sophisticated warning concept, mission system fitted with long range sights and accurate firing controls ... resulting in unmatched maneuverability, low vulnerability, highly lethal weapon system and low maintenance workload. The final qualification of the HAP and UHT versions at the end of 2008 gives the opportunity to make an assessment of the technical achievements and to give an overall status of the program: definition of the different versions (HAP for France, UHT for Germany, ARH for Australia, HAD for Spain and France), number of delivered helicopters (50 at mid of 2009) and perspectives.

1. INTRODUCTION

After the major step in the TIGER program achieved end of 2008 with the qualification of the final TIGER HAP and UHT versions, this paper provides a technical presentation of the TIGER, showing how performances are matching the operational requirements, the status of the program and the perspectives. It describes the operational context and requirements, the technical solutions and results, the program and deliveries status. The main innovative technical solutions are described.

The TIGER Main Development Contract was signed in 1989 by German and French governments with the two companies Aerospatiale and MBB, whose respective helicopter divisions were merged to create Eurocopter in 1992.



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Fig. 1: TIGER HAP version

2. EVOLUTION OF THE OPERATIONAL CONTEXT

2.1. Initial operational context

The initial operational requirements, in accordance with the cold war strategic situation, were focused on anti-tank versions (PAH2 for the German Army and HAC for the French Army), with an additional escort version for the French Army (HAP). The main purpose being the fight against large formations of tanks in central Europe, the TRIGAT-LR anti-tank system, developed for ground vehicle, was integrated as the main weapon system of the PAH2 and HAC versions. The HOT antitank missile was also part of the mission system, as well as Air-to-Air missiles for self-defence (MISTRAL for HAC and STINGER for PAH2). As the HAP mission was the escort of the HAC and air to ground support, it was optimized for air-to-air combat with MISTRAL Missile, an accurate and quick positioning turreted gun, and also unguided rockets.

The required trade-off between helicopter agility and stealthiness on one side, and high payload for effective weapon systems and endurance on the other side, led to the choice of a medium weight around 6 T, and to the main design characteristics.



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Fig. 2: TIGER UHT version

2.2. Evolution of the requirements

The operational requirements were adapted after the end of the cold war to multi-role versions: UHT for the Germany, ARH for Australia, and HAD for France and Spain. The need for operation at high temperature and with higher take-off weight also led to increase the HAD engines power, with the new MTR 390-E.

An important fact is that the operational requirements leading to the main design concepts (agility, stealthiness, medium weight...) are still valid after the evolution of the operational requirements.

2.3. The current versions

All the versions are based on the common vehicle and basic system, with limited differences. The mission system is specific to each version.



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Fig. 3: TIGER UHT version with 70mm rockets and TRIGAT-LR pods

UHT (Unterstützungs-Hubschrauber TIGER): developed for the German Army, it is fitted with the TRIGAT-LR and HOT Air to Ground missiles, unguided 70 mm rockets, STINGER Air to Air missiles and one or two 12,7 mm gun pods. The visionics includes the OSIRIS Mast Mounted Sight for targeting and the Piloting Vision System for day and night piloting and targeting. This latter is made of a Pilot Sight Unit installed in the H/C nose and of an Integrated Helmet System, fitted with Image Intensifiers Tubes, for each crew.



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Fig. 4: TIGER HAP version with 68 mm rocket pods

HAP (Hélicoptère d'Appui / Protection): developed for the French Army, it is fitted with a 30 mm turreted gun, 68 mm unguided rockets and MISTRAL Air to Air missiles. The visionics includes the STRIX Roof Mounted Sight, a Head-Up Display in the pilot cockpit and a Helmet Mounted Sight, fitted with Image Intensifiers Tubes, for each crew.

ARH (Armed Reconnaissance Helicopter): developed for the Australian Army, it is based on the HAP version and additionally offers the HELLFIRE Air to Ground missile, with an enhanced version of the Roof Mounted Sight fitted with a LASER designator and a LASER Spot Tracker.

HAD (Helicóptero de Apoyo y Destrucción / Hélicoptère d'Appui Destruction): developed for the Spanish and French Armies, it is based on the HAP version and additionally offers the SPIKE (for Spain) and the HELLFIRE (for France) Air to Ground missiles, with an enhanced version of the Roof Mounted Sight fitted with a LASER designator and a LASER Spot Tracker. Enhanced MTR390-E engines allow operation at high temperature / altitude and with increased TOW.

Each version is fitted with a radio suite and data links in accordance with the requirements of each country for compatibility reason.



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Fig. 5: TIGER HAP version

3. THE TECHNICAL SOLUTIONS

As the use of existing functions or modules was not a constraint for the TIGER, designers had the opportunity to directly issue the technical specifications from the operational requirement, and then study original technical solutions. For instance, stringent maintainability requirements were taken into account from the start of the development in all the H/C parts. It must be emphasized that the evolution of the operational requirements during the development mainly impacted the mission system definition, but not the vehicle and very few the basic avionics.



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Fig. 6: the Mast Mounted Sight (UHT version)

3.1. The design concepts

The H/C operational requirements are:

- It must be able to operate without heavy infrastructure and be autonomous, allowing amphibious and overseas operations.
- It must have the best maneuverability to get superiority and reduce its vulnerability.
- It must be adapted to a medium size nation by reducing the logistics constraints.
- Its weapon system must provide high lethality with minimum ordnance.

The solution was a 6 tons, agile and stealth platform fitted with very accurate weapon system and the following main design concepts:

- One common basic helicopter with specific mission equipment packages for each version,
- Keep a limited TOW allowing to increase survivability (6,1 t to 6,6t),
- Tandem cockpit, pilot in front,
- High ammunitions delivery accuracy
- Firing domain similar to flight domain
- Range for self deployment
- Use passive system to avoid detection,
- Survivable helicopter system,
- Ability to sustain intensive operations.

3.2. The technological break through

To answer to the following requirements at the same time, technical breakthroughs are needed in all the main parts of the H/C: airframe, mechanics and rotors, engine, avionics and mission system, which are described in the next chapters.

3.3. Composite airframe

Intensive use of composites is the main characteristics of the airframe:

- 77% of the structural weight is from composites: carbon sandwich or monolithic carbon,
- No longer cracks problems nor corrosion, as demonstrated by test on ground with a real airframe: after ageing in high humidity environment, the complete 6000 flight hours lifetime was simulated on the airframe by

applying the stresses cycles equivalent to the take offs, landings and other events encountered in the whole H/C life. The airframe showed neither crack nor ageing of the composite at the end of the test.

- Damage tolerant: the test of ageing described in the former chapter was performed after the application on the airframe of the damages representative of the H/C life (for instance battle damages), and the repair of these damages, allowing qualification of the repair process.
- No airframe overhaul
- Quick repair in case of battle damage: in case of minor damage, no immediate action is required. For other damages, the procedure is to perform a quick repair on location with riveted aluminum, then to complete with a definitive repair which will provide again the full capacity.
- High survivability and crashworthiness through multiple load paths: the required level of 10,5 m/s vertical speed for crashworthiness is reached thanks to the first effect of the landing gear (speed decrease from 10,5 to 7,5 m/s) and the second effect of the deformation and crushing of the lower airframe section. The crashworthiness was demonstrated for the first time in real conditions with a complete airframe at 10,5 m/s vertical speed.



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Fig. 7: Mating of front and central fuselages

3.4. Landing Gear

The high energy absorption landing gear was demonstrated at a 6m/s vertical speed hard landing without any damage. The front landing gear is fitted with two dampers, low pressure and high pressure.

3.5. Main and tail rotor

The tail rotor is a three-bladed, 2.7 m diameter spheriflex rotor, which features an integral titanium mast/hub. The tail blade, made of composite material, has a fork-shaped attachment.

The tail rotor high power provides very high yaw rate capability to the helicopter: it is capable of pivoting through an angle of 40° around the yaw axis in 1.5 seconds from the moment that the yaw pedals are activated, and up to 120°/s stabilized yaw angular speed. The required ballistic protection is ensured by the control system mounted inside the mast and the blades.



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Fig. 8: Main rotor head

The hinge less fiber elastomeric main rotor offers high (virtual) flapping hinge offset for high translative and rotative accelerations and provides exceptional maneuverability to the helicopter.

The hingeless rotor head simplifies the maintenance considerably compared to the traditional hinged type. The rotor hub consists of upper and lower composite plates connected by a titanium centre-piece. The two bearings (radial bearing inside and conical bearing outside) transmit lift forces, blade flapping and lead lag moments to the rotor hub.

The blade design is characterised by high performance airfoils and specific blade tip geometry, for improved performance and low noise. The blade is made of composite material using glass and carbon pre-pegs. The blade and blade tips are interchangeable.

The blade root is characterised by flexible areas, which replace the conventional mechanical flapping, and lead lag hinges. A visco-elastic damper on each blade assists drag damping.

3.6. Gear boxes and transmission

3.6.1 Main Gear Box

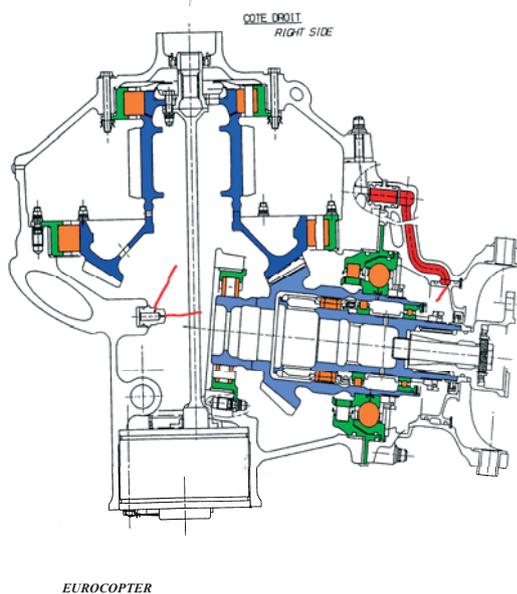


Fig. 9: Main Gear Box

- The MGB very low Weight / Power rate and high reliability and lifetime (6000 flight hours) are achieved through use of magnesium for the casing, integration of almost every bearing race, eliminating fretting corrosion, and deep nitriding of every gear teeth.

- The achieved performance is a weight of 252 kg including accessories for a main rotor power of nearly 1300 kW.

- All functions, including the two alternators, the air conditioning system compressor, the hydraulic pump and the oil cooler system are part of the MGB assembly. Added to the capability to clutch / de-clutch the LH engine input without engine power-off, it provides the APU function, eliminating the need of a conventional APU.

- The lubrication system reliability is increased by the integration of the oil conducts (total 5 meters). Its design, in conjunction with the capability of deep nitriding treated parts to keep their performance at high temperature, was intended to comply to the requirement of 30 minutes dry run after total oil loss. In fact, more than one hour was demonstrated.

- The SARIB type suspension, using damping effect of flapping masses, provides very low vibration level at the seats (0,02 g at pilot seat at 120 kts, reducing crew strain) and at the Roof Mounted Sight interface.

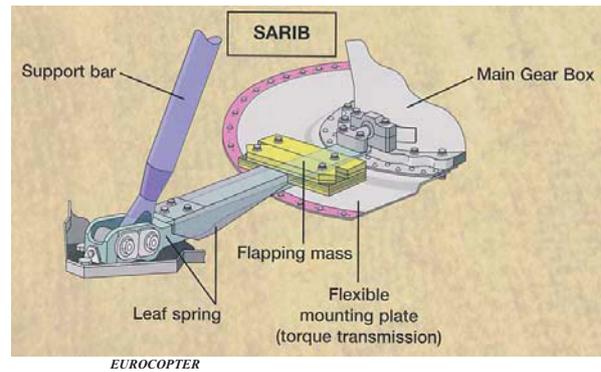


Fig. 10: SARIB suspension

3.6.2 Rear transmission

- It is a supercritical transmission, using only one bearing and a composite shaft. It provides low weight and ballistic protection.

3.7. Engines

The MTR390-2C engine, developed specifically for the first TIGER versions HAP and UHT, is also used on ARH. Each of the two engines provides 876 kW Maximum Continuous Power and 960 kW Take Off Power. For the new HAD requirements (TOW up to 6,6 T and high temperature environment), it was upgraded to the MTR 390-E version.

An important function for piloting workload reduction, developed for the first time, is the Power Margin Indicator, which displays on the Multi Function Displays the engine power available at any time in a simple and unique parameter. It avoids the need of checking several different engine parameters (torque, power...).

3.8. Vehicle performances

The requirement of high agility is fulfilled thanks to performances like:

- VNE: 175 kts

- Load factors: -1 g to + 3 g.

- Sustained turn at permanent 60° roll angle without altitude loss

- Maneuverability: Complete barrel roll in less than 5 s.

- H/C is capable of pivoting through an angle of 40° around the yaw axis, in 1.5 seconds from the moment that the yaw pedals are activated. Up to 120°/s stabilized yaw angular speed.

- Acceleration from 0 to 110 km/h: 10 sec (Power margin: 10%)

3.9. Man – Machine Interface



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Fig. 11: The rear cockpit

In order to fulfill the mission in hostile environment, the crew must be supported by effective helicopter interface for all the tasks (piloting, communication, navigation, observation, aiming and firing...), requiring in such a complex system a very elaborated Human - Machine Interface. Nap-On-the-Earth flight for instance required to develop an HOCAS concept (Hands On Controls and Sticks) covering the main tasks the crew must complete, and the capability to pilot "head up". It is achieved by the availability of numerous controls on the grips combined with the availability of all the task related information on the different Displays.



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Fig. 12: The HAP Helmet Mounted Sight / Display

The crew workload is also decreased by PMI (Power Margin Indicator), described in Chapter 3.7.

The H/C architecture itself is optimized for piloting in difficult conditions: the pilot seat in front offers the best possible outside vision.

3.10. Avionics

The basic avionic system is mostly common to all versions, with the exception of the functions specific to each country (i.e. radio-communication and radio-navigation).

It includes navigation, communication, autopilot, electronic warfare self protection and cockpit controls and displays including a digital map generator. The main aircrew interface is performed via the four Multi Function Displays, two in the pilot position and two in the gunner position, two Control and Display Units, one in each crew position, and Hands On Collective And Stick (HOCAS) controls for main, frequently used functions.

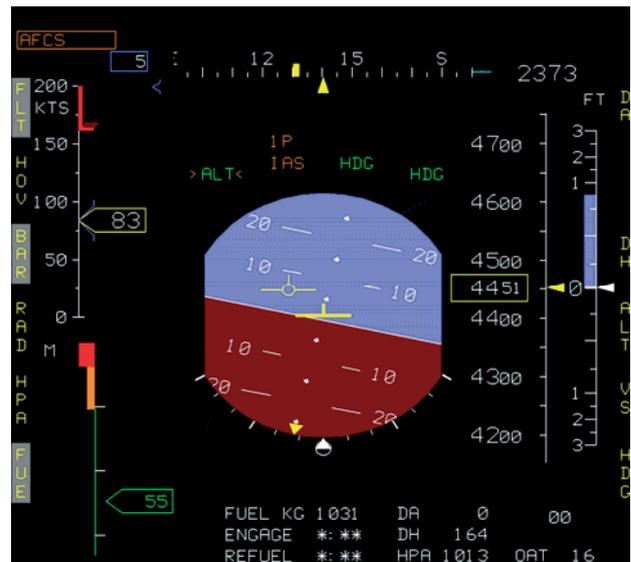


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Fig. 13: Example of Multi Function Display page

The most remarkable aspects are:

- The AFCS with the Tactical mode, the LOS mode (automatic alignment on the Line Of Sight) and the gun recoil compensation.
- The architecture based on a dual redundant 1553B Mil Bus, with Remote terminal Units for the introduction on the Bus of data generated by vehicle and engines,
- The redundancy of all critical functions (computers, navigation system, Automatic Flight Control System, Multi Functions Displays, communications): redundant equipments are physically installed in different helicopter areas and supplied by different power bus bars to decrease vulnerability,
- The sophisticated warning concept: warnings are classified and presented to the crew depending on their criticality (immediate action required, action required...) and are stored for maintenance. Presentation to the crew can be on displays or audio. The advantage is to decrease the crew workload by presenting only what is relevant to the mission. The pages related to a given warning are automatically available to the pilot (DO LIST for instance)

3.11. Mission system



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Fig. 14: Mistral and 68 mm Rockets launchers

The Mission Equipment Package is specific to each version in order to fulfill the different operational needs. It is built around a redundant 1553B Mil Bus, and managed by 2 main computers (offering full redundancy of functions) and a specific data concentrator which performs interface between all the different controls (for example weapon grips) and Mil Bus.

An Innovative boresighting concept, guarantying interchangeability of sights and weapons has been developed, avoiding obligation to perform logistic time consuming operations in case of equipment exchange.

Following complete HMI loop (paper design, evaluation on simulator, then evaluation in flight), an intuitive HMI and associated clear crew role allocation have been set up, allowing an easy employment of 3 or 4 different weapons, depending on the version, using 4 different sights optimizing crew workload.

Prepared firings (long range) will be performed with the main sight, using magnification and LOS stabilization capability. Opportunity firings (short range) will be performed with Helmet Mounted Sights.

The UHT MEP derives from PAH2 and includes the TRIGAT-LR and HOT anti-tank missiles, 70 mm unguided rockets and 12,7 mm gun pods. The main sight is the OSIRIS Mast Mounted Sight and the night piloting uses the Infra-Red Pilot Sight Unit or Image Intensifiers Tubes, both displayed on the Integrated Helmet System. The challenge of the Mast Mounted Sight integration was to install on the rotor mast the 125 kg Sight Head, supplied through the rotor with electricity, pressurized air to keep the Sight Head internal over-pressure, liquid for the window washing and coolanol for cooling different parts like the IR optics and camera. The choice of location of the vibration nodes in the rotor-mast / Sight Head set and the sophisticated Sight Head 3-stages stabilization system provided exceptional ranges to the TV and IR sensors, in line with the Missiles ranges.

For all the other versions, the MEP is based on the HAP version. It includes the STRIX Roof Mounted Sight, Helmet Mounted Sight and Displays with Integrated Image Intensifier Tubes, a 30 mm chin-mounted turreted gun, unguided Rockets and the MISTRAL air-to-air missile system. The 30 mm turreted gun integration was the main constraint of the front fuselage design, due to the need to install the 165 kg turret, to design the structure to withstand the severe firing recoil forces and to install the ammunition boxes and supply path. The very demanding requirements for gun firing accuracy were reached thanks to sophisticated firing control system: the target trajectory, speed and acceleration are computed from the data delivered by the STRIX Roof Mounted Sight - optimized for Line-Of-Sight accuracy and high speed - the H/C dynamics are delivered by the navigation system. The real time computation of the future target position is performed by a high order non linear Kalman filter, anticipating the relative target movements and bullet ballistics, and refreshing at high rate the gun position in azimuth and elevation. Additionally, and in order to stabilize the platform during firings, the gun elevation and bearing data are introduced into AFCS control laws to generate a gun recoil compensation signal. This allows the crew to obtain negligible heading, roll and pitch perturbations, which helps the gunner to aim more accurately. This accuracy and high dynamics capability, with the very large turret angular range in azimuth (+/- 90°) and elevation (-25° to + 28°) provides the H/C with exceptional air-to-air and air-to-ground capability with the only load for the crew to steer the sight to the target. The turreted gun allows firing in the complete H/C flight envelope.

An exclusive Lower Air Speed Sensor, based on the rotor blades positions, is used for the domain when the conventional air speed sensors are not precise enough, improving the accuracy of the unguided rockets when fired from hover for instance.

The Mistral air-to air missile is fitted with a complete firing control, allowing targets engagement in axis and off axis, in a real combat domain, hover to VNE. The basis of missile firing control is the same as for gun firing control. In addition to helicopter and target parameters given by same complex algorithms of gun firing control, a specific module provides cues to the crew to pilot the helicopter at the best attitudes for launching the Mistral missile.

The HELLFIRE air-to-ground missile is integrated in the Australian ARH version and in the HAD version. The high stabilization performance of the Roof Mounted Sight, fitted for these versions with LASER designator, allows Hellfire firing at long range with autonomous designation. The SPIKE-ER air-to-ground missile is also integrated in the HAD version.

3.12. EMI, signatures

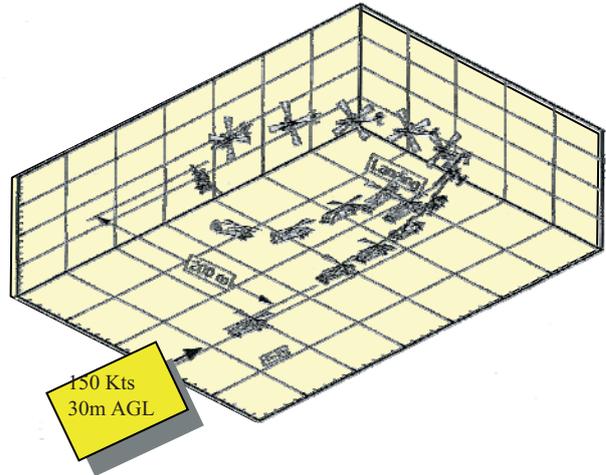
The low IR signature is reached by the integration of the engines into the fuselage and by use of specific exhaust gas dilution system driving them up to the rotor. Low RADAR equivalent surface is provided by small volumes airframe, made of composite carbon fiber absorbent. Mainly the reduced front surface allows a very high efficiency in this direction.

The EMI NEMP, LEMP, NBC standards are fulfilled and demonstrated by test campaign in state-owned facilities.



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Fig. 15: EMI tests



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Fig. 17: 360° turn quick stop maneuver

The attention paid to crew safety resulted in exceptional crashworthiness capability, adding to the survivability performance of an H/C optimized for NOE.

3.13. Results



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Fig. 16: Aerobatic performance

In the field of H/C maneuverability, impressive results are obtained as demonstrated by the aerobatic performance and the capability to perform for instance obstacle avoidance (Dolphin) and quick stop with low pilot load, i.e. Cooper Harper Rating level one. Quick stop in 360° turn from 150 kts is performed in a 200 m path width. The operational advantage is to avoid exposure by very effective Nap-On-the Earth flight, and to allow the pilot nearly unlimited maneuvers in air combat or other emergency situation. The ability to NOE flight combined to the low detectability and passive stand off mission system answers to the operational requirement of survivability. The mission reliability is also reached thanks to the exceptional accuracy of the weapon systems. For instance, Hellfire missile range of 7km with a metric accuracy was demonstrated with autonomous LASER designation. The turreted Gun accuracy and angular speed allows effective air-to air superiority at short range, although the MISTRAL missile extends it up to medium range, thanks to the very short time needed between the target acquisition and the firing, as a result of its large target acquisition field of view.



Photo EUROCOPTER

Fig. 18: HAP deck landing test with high ship roll angle

An additional important operational capability for overseas operations was demonstrated for the HAP version with the navalization qualification performed during several dedicated campaigns on French Navy ships.

The very stringent maintainability requirements have resulted in a ratio of around 4 to 5 Maintenance Man Hour per Flight hour, remarkable for such a complex H/C. The on-condition maintenance concept is now demonstrated.

4. PROGRAM STATUS

The current total backlog is 206 TIGERS with four customers (France, Germany, Australia and Spain). The status of deliveries mid of 2009 is:

- 20 HAP to France (40 ordered)
- 10 UHT to Germany (80 ordered)
- 15 ARH to Australia (22 ordered)
- 5 HAP to Spain (6 ordered)



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Fig. 19: Final Assembly Line

4.1. HAP / UHT operational deployment



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Fig. 20: HAP deployment

The TIGER program achieved a major milestone end of 2008 with the qualification of the final HAP Standard1 and UHT Step 3 versions.

These versions are already operated by the French and German Armies thanks to very complete and effective training and logistics activities and resources. The training is performed in common centers, at Le Luc (France) for the flying crews and in Bückeburg (Germany) for the maintenance crews. The EFA (Ecole Franco-Allemande) in Le Luc (France) is equipped with full flight simulators and several TIGER H/C, the Bückeburg center with

maintenance simulators.

A first overseas TIGER deployment is planned by French Army mid of 2009.

4.2. ARH / HAD qualification

The Australian version ARH will complete its Initial Operational Test and Evaluation phase, and start the customer operational capability test with 3 H/C in September 2009. All the H/C tests will be completed by end of 2009, closing a development started early 2002. The Operational Capable Helicopter status will be reached end of 2010.

The new version ordered by France and Spain (HAD) is in development, with a first helicopter already flying since end of 2007. SPIKE Air-to-ground missile firings were already demonstrated, HELLFIRE firings are planned in September 2009. The qualification is planned in 2013, and the ordered quantities are: 40 for France and 24 for Spain.

5. PERSPECTIVES

5.1. Current evolutions

The TIGER platform, which includes all the necessary basic features, is able to be easily upgraded with new weapon systems, like the Laser guided rockets, for which pre-studies are already launched for the UHT and HAD versions.

The preparation of the external operations by the French Army was the opportunity to fit the TIGER with equipments and capabilities supporting for instance high altitude operation or very sandy environment.

5.2. Export

Australia and Spain already selected the TIGER in the past. The versatility and adaptation of the TIGER to the respective needs of most part of potential customers will probably increase again the TIGER community in the near future, the start of operational phase by the first customers showing furthermore the adequacy between the performances and the operational requirements. The already implemented facility for training of flight and maintenance crews is a great opportunity for every new TIGER user.

6. CONCLUSION

This paper has showed how the operational requirements were flown down to the technical requirements and the definition of the TIGER and how the achieved results demonstrate the success of the process. Thanks to a number of technical innovations, the TIGER will be for numerous years the most advanced helicopter in its category. It is now able to start its operational life and become the new reference for attack helicopters.



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Fig. 21: HAP and UHT versions

Abbreviations

AFCS	Automatic Flight Control System
APU	Auxiliary Power Unit
ARH	Armed Reconnaissance Helicopter
EFA	Ecole Franco Allemande
EMI	Electro- Magnetic Interference
HAC	Hélicoptère Anti-Char
HAD	Helicóptero de Apoyo y Destrucción / Hélicoptère d'Appui Destruction)
HAP	Hélicoptère d'Appui Protection
H/C	Helicopter
HMI	Human-Machine Interface
HOCAS	Hands On Collective And Stick
IR	Infra Red
LEMP	Lightning Electro Magnetic Pulse
LOS	Line Of Sight
MGB	Main Gear Box
MEP	Mission Equipment Package
NBC	Nuclear, Bacteriological, Chemical
NEMP	Nuclear Electromagnetic Pulse
NOE	Nap On the Earth
PAH2	Panzer Abwer Hubschrauber 2
PMI	Power Margin Indicator
SARIB	Système Anti-Résonnant Intégré à Barres
TOW	Take Off Weight
TV	TeleVision
UHT	Unterstützungs-Hubschrauber TIGER
VNE	Velocity Never Exceed

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