ID 130

FLIGHT LOOP DEVELOPMENT FOR TRAINING SIMULATION BY INDUSTRY LAST PROGRESS

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Introduction

Improve safety is one of highest Eurocopter's priority. Strong efforts are done to improve Eurocopter helicopters reliability. Nevertheless, statistics clearly demonstrate that human error is at origin of a great majority of accidents. Therefore, efforts should be done to improve helicopter pilots training especially in critical conditions. As for airplanes, full flight simulator is one of the best mean to intensively and safely train pilots in most degraded conditions which are very often not possible to realize in flight. To be efficient and to avoid any negative training, high level of representativeness is required for simulators including simulated failures. Others needs, such as military ones with more and more complex missions, also push toward this same high level.

This high level is formally qualified by authorities by reference to dedicated standards such as JAR FSTD H or FAR part 60 which define strict requirements on used material and software. For military applications, theses standards are completed in relation with customers with tests inspired by ADS33 tests or additional ones to validate specific training sequences. To achieve this level, simulator material is of course very important with especially a perfect replica of cockpit and high quality visual and motion. But whatever efforts done on material, pilots could have the impression to be in flight only if Flight loop models in charge of simulating helicopter flight behavior are representative enough.

Flight loop is a set of 3 models: helicopter, engine and AFCS (Automatic Flight Control System) including controls kinematic and laws. Flight loop allow simulating flight mechanics on ground and in flight in function of pilot controls inputs and flight conditions including weight and center of gravity, atmospheric conditions, wind and turbulence. Functions required to ensure a complete training such as simulation in degraded conditions and predefined failures are included in theses models. In fact, Flight loop is the simulator core which makes living motion, visual and most of the cockpit instruments in function of controls activation done by pilots and conditions inputs defined by instructor.

Eurocopter has nowadays more than ten years of experience in development of high level flight loops and has acquired a high expertise with a process now well mastered. To achieve this highest level of flight simulation representativeness, every development phases are important from initial data acquisition to final qualification process.

The main objective of this presentation is to introduce the way Eurocopter use to achieve the highest level for simulator in order to improve

pilots training capacity and consequently flight safety. This presentation is broken down into 3 parts: Eurocopter experience in simulators development is firstly presented, then means and methods used by Eurocopter in simulators development is explained and lastly, a synthesis of improvements being done in modeling, development process and qualification standards is exposed.

Eurocopter experience in simulators

Eurocopter has more than ten years of experience in development of high level flight loops with 16 Flight loop developed or being developed. Among them, 11 have been formally qualified at a level FFS D or FTD 3 (the highest levels for a training simulator), 5 other ones will be qualified before end of 2012.

Simulators already in operation

Indeed, end of 90's Eurocopter has started with Thales the development of 4 simulators FFS level D for the new training simulation center Helisim, a joint venture involving Eurocopter, Thales and DCI (Defence Conseil International). From 2002, Helisim became the first centre in the world equipped with Eurocopter helicopters Full Flight Simulator (FFS) level D. Two convertible full flight simulators that can receive four cabins are operational and intensively used (20h/24h all days). There are 2 Super Puma MK1 (AS 332 L1) and MK2 (AS 332 L2) and 2 Dolphin N2 (AS365 N2) and N4 (EC155). From 2008, a fifth cabin EC225 and an additional full flight simulator totally dedicated to the NH90 (TTH) are also installed in Helisim. Specific trainings for military missions are available on this NH90 simulator.

Four similar NH90 simulators are installed in Bückeburg (2), Fassberg (1) and Hollzdorf (1) (BWB Germany).

1 - FFS NH90 Bückeburg

Eurocopter has also developed Tiger simulators at the same level for French Army (HAP TATM), Australian Army (ARH) and Spanish army (HAP-E).

Three EC135 simulators (one for Eurocopter Deutschland, one for American Eurocopter and one in Poland) and an other EC225 with the new FADEC (Full Autority Digital Engine Control) version engine for Eurocopter UK in Aberdeen have been developed and there all are qualified FTD level 3.

2 - FTD EC225 Aberdeen

Simulators in development

Before the end of this year, 4 new simulators will be qualified: an EC635 for Armaswiss, two NH90 (one NFH for Netherland

and one TTH for Australia) will be qualified FFS level D and a Dolphin N3 (AS365 N3 with three different autopilot and avionics configurations) for Heliunion will be qualified FTD level 3.

3 - FTD Dauphin N3 for Héliunion

The new challenge for Eurocopter is the development of a FFS level D for the EC175, the new Eurocopter helicopter. The new difficulty for this simulator development is to follow the development of the real aircraft in order to ensure simulator availability in the same time as the first serial aircraft delivery. That means to continuously adapt Flight loop models to the different evolutions inherent to the tuning of the prototype. These evolutions may impact not only the aerodynamic configuration such as horizontal stabilizer or cowlings but also autopilot stabilization laws, engines regulation laws (ECU) and avionics equipments. Achieve the same level as other simulator for a simulator developed in the same time than the real aircraft is therefore adding new difficulties and is a first experience for Eurocopter. This scenario will be reproduced for future projects since nowadays customers more and more require available training simulator with new helicopter delivery. In order to achieve this challenge, Eurocopter will apply all the experience and expertise acquired during all these numerous developments. It will be the key of the success to fully satisfy this new customer requirement.

4 - The EC175, the new Eurocopter helicopter

Means and methods

Flight loop development process

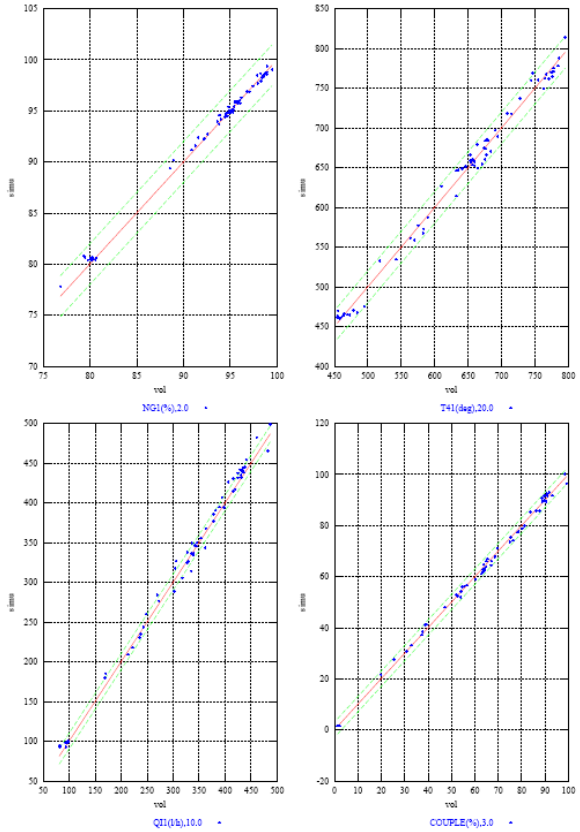
This rich experience has allowed Eurocopter to progressively organize and consolidate an industrial development process based on three main steps

In a first step of initial development, efforts are done to clearly define simulator specifications in function of helicopter specificities and training needs. Based on these specifications, helicopter model currently used for design objectives is adapted. In parallel engine model is developed and carefully validated in stand alone conditions with especially full consistency to reference performances in all flight domain. AFCS software is rehosted. Finally Flight loop is generated by connecting all these models and validating its functioning on offline environment.

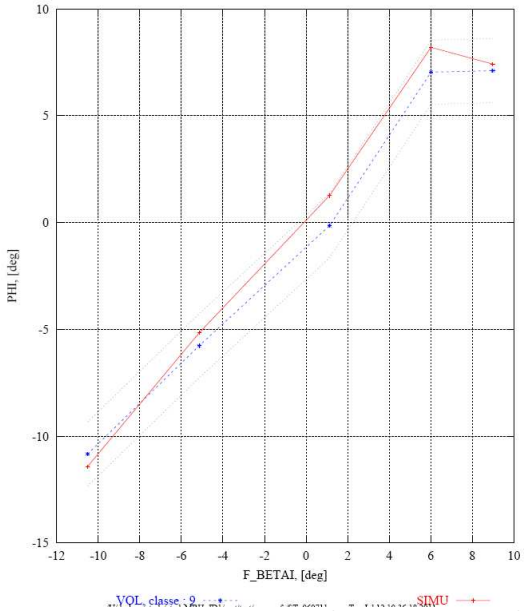
In parallel, flight tests required for qualification are realized in a dedicated campaign. Indeed, experience clearly show that flight tests realized during helicopter design and certification are not fully relevant since configuration evolutions and test non compliant to expected ones as defined in simulation qualification standards. Usage in a short time of only one helicopter with a configuration fully consistent with simulator one favors generation of high quality reference flight tests data base. Deep analyses, defined in a precise quality plan, is applied during and just after this flight tests campaign to ensure full respect standard tests definition and high quality and consistent measurements. This process will allow later a correct flight loop tuning and qualification.

In a second step, pretuning tasks are done. A complete tuning is done by reference to flight tests and inside standard tolerances for all stabilized flights. This tuning is done by adjusting physical

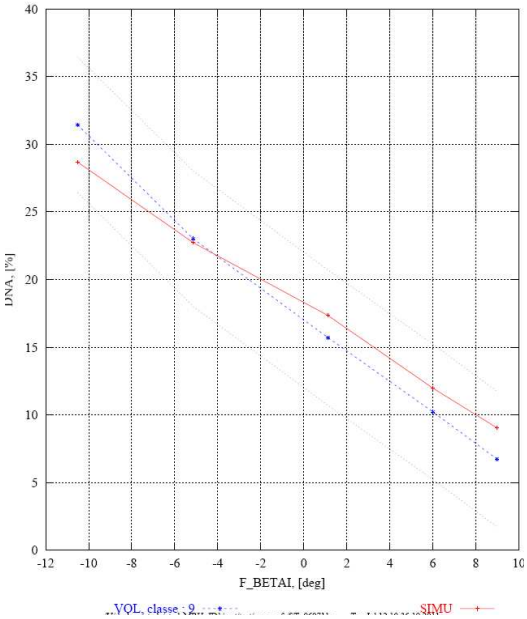
(mainly aerodynamic) characteristics only and is definitive since usually fully satisfying pilots. Moreover, performances of the aircraft describe in the flight manual have to be compliant on the simulator in the entire flight envelope.



5- NH90 static tests - Comparison of engine parameters flight vs. simulation results



6 - NH90 Directional static stability - flight vs. simulation for bank angle



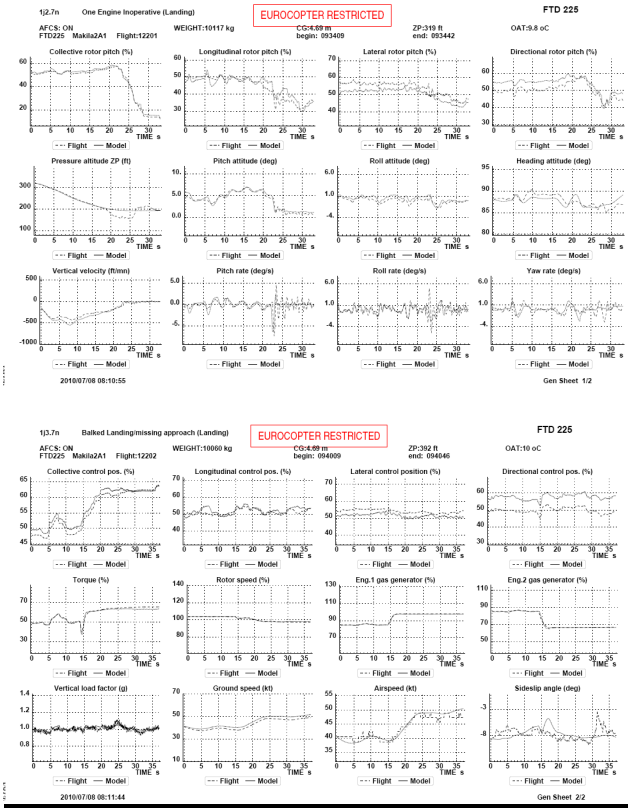
7 - NH90 - Directional static stability flight vs. simulation for pedal position

For dynamic aspects such as control responses or short and long term responses, a first pretuning is done to ensure representativeness enough to start evaluation with pilots in correct conditions. Indeed, experience shows that dynamic tuning mainly consisting to adjust control sensitivity and helicopter damping may afterward be criticized by pilots implying to choose different alternative ways to both respect standard tests tolerances and satisfy pilots' judgments.

Third step of complete tuning can start as soon as simulation environment including cockpit, control loads, visual and motion are at sufficient levels to ensure correct and reliable pilots' evaluations. To check if this state is reached, Engineers Functional Assessments are organized to evaluate and, if needed, correct what can be checked by engineers. These sessions are also organized to ensure that integrated Flight loop and simulator are representative enough to start pilots' evaluations. Pilots' subjective evaluations are then conducted according to a complete tests plan. All flight domain is progressively evaluated in normal and degraded conditions. Iterative tuning process is realized to ensure the best compromise between objective standards tests and subjective pilots' judgments. There is sometimes a need of compensating in Flight loop some defaults inherent to simulator environment limitations such as motion or visual near the ground but these compensations should be done carefully in order to avoid to degrade flight mechanics representativeness and negative training.

Once Flight loop fully tuned and satisfying both objective requirements and pilots' judgments, a complete qualification process is applied by Eurocopter to contribute to the simulator

qualification by providing three important deliveries. First of all, a POM (Proof Of Match) superimposing flight tests and simulations results within tolerances is realized on Eurocopter offline environment and includes all required tests: basically JAR/FAA Standards tests, optionally ADS33 like tests and training sequences tests for military applications. Target of this POM delivery is to demonstrate that flight loop delivered by Eurocopter is compliant to standard requirements. This POM is usually included in the QTG (Qualification Tests Guide) and may allow authority to compare tests recorded on simulator with ones provided by Eurocopter. A second important delivery is the VDR (Validation Data Roadmap) which provide list of reference flight tests used to qualify performances and handling qualities. VDR also precisely justifies compliance of helicopter configuration used for flight tests realization with useful explanations about measurements and way of conducting tests in flight. Lastly, a tests plan results can be delivered if requested to give information about tests conducted by Eurocopter engineers and pilots during simulators assessments with target to demonstrate that all flight domain including degraded conditions have been tested with correct results.



8 - POM sheet example – FTD EC225 Balked landing/missed approach

People involved

Experimental flight tests pilots

The first requirement in order to achieve a high level for a simulator is the quality of flight tests used to develop and tune models. A dedicated campaign is done by Eurocopter experimental flight tests pilots who have the best helicopter knowledge and experience to understand qualification expectations and to appropriately realize flight test. They are especially used to be very precise and repetitive in maneuvers.

Quality of the flight tests is a major key to ensure a correct Flight loop models tuning and compliance demonstration. Indeed, if the flight test campaign is not precise enough and if there are dispersion or inconsistencies in the flight results you have to artificially degrade flight mechanics model to satisfy tolerances required by the qualification standards. Then, on the simulator you may have some pernicious effects induced by this wrong tuning. Only a dedicated flight tests campaign using one helicopter in compliant configuration and realized by helicopters industry with experimental flight test pilots can ensure this required quality.

The second part of a simulator development where Eurocopter involve experimental flight tests pilots is the complete validation of the simulator. They have the deepest knowledge of helicopters, they have strongly contributed to develop, adjust and qualify. Their job with a fully recognized expertise is to finely assess and analyze day after day the behavior of the real aircraft during its complete development. They are very used to comprehend all details of the aircraft. Moreover, with such an experience, they are quite alone able to evaluate and validate degraded flight conditions simulation. Indeed, during the development and certification of the real aircraft, they have to test many degraded situations that an operational pilot will never see. In a simulator, degraded flight conditions simulations are the key of an efficient training so it is very important to tune and validate these degraded conditions with a pilot who perfectly knows them.

Design office engineers

In the same way, flight loop development and its tuning is done by the same design office engineers who have participated to the helicopter development. These engineers have a complete knowledge of helicopter characteristics. Flight loop tuning is therefore optimal since based on high quality simulation models and assessed and tuned by most competent design office engineers in close

relation with the same flight tests team as for helicopters development.

In addition, inside the design office there are all the specialists for every part of the aircraft and it is easy to find additional information that can help to correct or improve simulator behavior even in very special conditions such as degraded ones. For instance, to implement failures, design office engineers have full access to all analyses and documentation done during the development and certification of the real aircraft.

Moreover, there are perfect technical exchanges and understanding between these engineers and flight tests pilots since used to work together during helicopter design. This favor efficient evaluations and analyses during simulator assessments sessions.

All these conditions are of course optimal to ensure the best simulation result.

OEM (Original Equipment Manufacturer) part in a simulator

Point of view of major helicopter manufacturers

With the objective to improve safety and because of the increasing complexity of embedded systems, Eurocopter promote OEM parts usage in simulators. This point of view is shared by the fourth major helicopter manufacturers (Bell, Sikorsky, Agusta and Eurocopter) in a letter commonly written to underline the importance of OEM parts. (See annex 1)

Advantage of OEM parts in a simulator

Indeed, helicopter manufacturers are the only ones to have the full knowledge of their helicopters and especially their aerodynamics characteristics and of all the equipments behavior in nominal conditions or in case of malfunctions. In the same way, data package issued from equipments manufacturers themselves is mandatory to ensure realistic behavior in case of failures and to train pilots safely to react to these failures. For instance, Eurocopter systematically use engine manufacturer data packages and rehost its own embedded autopilot or fly by wire software.

Without original data package including flight loop models developed and tuned by helicopter industry, the identification of all parts of the aircraft has to be done in flight and it is necessary to perform a lot of flight hours in order to have minimum data to develop the different models in the simulator. One flight test hour is very expensive so to buy and use the original data package can be at the end good value for money. Moreover whatever the amount of flight hours, it is impossible to explore the entire helicopter flight domain which is very large. Only flight loop models based on helicopter manufacturer knowledge can both be tuned on flight tests in correct conditions and ensuring a correct extrapolation in the entire flight domain and even in limit or degraded conditions. By the way, it is not possible to have flight tests for most of the malfunctions (for example FADEC or Autopilot failures) so without original data package a compliant behavior in all nominal and degraded flight conditions cannot be fully ensured at a correct level.

Especially, a large part of training for pilots on a simulator is composed of failures and is useful to learn and assimilate the way to react against serious failures. It means that it is imperative to have the full exact behavior of the simulator when these failures are applied in order to avoid any negative training.

Improvements

It has been previously underlined that involvement of design office engineers and flight tests pilots in simulators development and a systematic utilization of OEM data package provide the best level of quality and compliance. Nevertheless, Eurocopter target is to still improve the quality of the training on simulator and consequently the safety. To achieve this target, Eurocopter is being working on three main axis of development.

Aerodynamics modelization

To simulate flight mechanics, Eurocopter use an advanced knowledge model called HOST (Helicopter Overall Simulation Tool) which is used for both helicopter design and simulation needs. Inherited from dozen years of development and research activities, HOST continuously take benefit of numerous applications experiences during not only helicopter design but also all simulations applications such as avionic benches and obviously training simulators.

Nevertheless, whatever efforts invested in flight mechanics modelization, helicopter remains difficult to simulate for two main reasons. First of all, flight domain is large with specific flights such

as manoeuvre around hover, durable flight near the ground, low airspeed, rear or side flights or vertical climb or descent fully unknown for an aircraft. Moreover, Helicopter is a complex machine with two rotors and high interactions between these rotors and body which significantly change in function of flight conditions.

The first improvement axis is in aerodynamic modelization of the helicopter where there are still parts not satisfactory such as rotor modelization at a level useable in real time conditions and interactions of rotor induced flow with body. These improvements require important effort by realizing and analyzing for instance wind tunnel tests or complete CFD calculations.

For example, in low airspeed flight conditions there are many interactions with significant combined effects between main rotor induced flow and horizontal stabilizer or vertical fin or body but also with the tail rotor and its flow. The induced flow of the tail rotor itself interferes with horizontal stabilizer and vertical fin. Then on these rear items, there is in the same time a part of the induced flow coming from the main rotor and an other part coming from the tail rotor. Today with progress being done on calculation power given by new processors and on CFD software capacity, it is possible to launch CFD calculations on the complete helicopter in specific flight cases in order to analyze the results and to improve the understanding of interactions on the different parts. That gives us the possibility to improve our modelization for these phenomenons and of course the representativeness of the aerodynamic model in all flight cases and especially low airspeed conditions including lateral or rear wind in hover. Experiences clearly show progress achieved by comparison to flight tests and a better satisfaction of pilots.

Other improvement axes are the rotor modelization to be enriched but keeping in mind that these modelizations should be compatible of real time constraints. Eurocopter is especially working on rotor induced flow, rotor head aerodynamic and blade aerodynamic polars by refining effects such as Mach, stall and roughness. Fenestron simulation is also deeply worked with usage of specific wind tunnel tests and improvement of shroud effect modelizations

Embedded software

The second improvement axis is to include as much as possible simulation constraints in the development of new embedded equipments such as stabilization or regulation systems in the autopilot or the engine. For new helicopter, these specific constraints are evaluated and integrated as much as possible in the software specifications at the beginning of development.

Some functionality are of course not used in the real aircraft as the possibility to quickly initialize the model directly in flight or to make a freeze. These specific simulators functions may be very difficult and even impossible to integrate in the embedded software from the beginning since this would be not in line with safety and certification requirements. An alternative solution is to use the same tool as the one used to design and generate embedded software. This allow by addition of specific simulator functions in this same tool to generate rehosted software for simulators with full reuse of the embedded software laws. Moreover this makes easier to update software later

This process gives more opportunity to use these embedded software on simulators with the minimum amount of modifications. Of course, this is a big guaranty of compliance with the real helicopter but this policy could also reduce cost of simulator development because implying less adaptations effort for simulator usage.

Qualifications standards

The third improvement axis concerns qualification standards. Indeed, Eurocopter judge that JAR/FAA standards are today a good reference for performances and handling qualities aspects concerning Flight loop. These standards usefully complete pilots' evaluations and should ensure a correct flight mechanics representativeness if they are correctly applied that means standards application should be still more controlled. Nevertheless, some tests or tolerances are still useless or restrictive and should be suppressed or replaced by other ones more useful. Others Eurocopter recommendations are about subjective evaluations which should be more formally controlled by a detailed tests plan defined in standards, as Eurocopter do with its tests' plans consolidated with end users and adapted to their training objectives. Lastly, OEM simulation package approach and evaluation done by helicopter manufacturer flight tests pilots should be more systematic and this principle should be integrated in standards

Eurocopter is involved in groups as ICAO 9625 to improve standards, always in a way to give authorities means to be able to qualify simulators with best criteria and adapted requirements. The simulator qualification standards for helicopter initially come from the airplanes ones. Consequence is that some tests are not fully adapted to helicopter and sometimes there are lacks concerning some specific helicopter flight cases.

These groups are not only involved in the QTG (Qualification Test Guide) tests but also in the level of simulators required for different training needs. Because training needs are very specific, it is very important to define the level of compliance necessary for each level of needs. For example, if the need is only training for missions' preparations, it is not necessary to have a complete representative helicopter in each flight case. To use the different mission equipments, a LTD (Light Training Device) may be enough. On the contrary, to train pilots for specific malfunctions such as autopilot failures, IFR fly without any stabilization, engine failures or tail rotor loss then a complete Full flight simulator is mandatory to set pilots in best representative conditions and to be sure to avoid any negative training.

The aim is to insure the best training of pilots while controlling simulators costs at a reasonable level.

Conclusion

Training simulators at the highest level of representativeness and compliance to the real aircraft is a major key to improve pilots' reaction capacity in degraded conditions and consequently the flight safety. Eurocopter has achieved to provide a large set of high level training simulators for quite every major type of its different helicopter families. Therefore, Eurocopter is now able to propose to its customers adapted, representative and qualified training means. For new helicopters, an affirmed trend is that major customers more and more requiring to buy the training means in the same time with their helicopters. Nowadays helicopter training simulation is becoming omnipresent and quite mandatory as for airplanes.

Progresses done are very important in helicopter training simulators development but because this activity is recent (at this high level) and still in evolution, helicopter manufacturers have to pay attention to the quality of the simulators developed not only by them but also by directly simulators' industries in the world. Full participation of design office engineers and flight tests teams allow to inherit of the best knowledge of the helicopter and consequently favor appropriate tuning and especially correct behavior simulation in degraded conditions. OEM parts usage in a simulator is an important lever to ensure a high level of quality and should be more recognized in qualification processes.

Progresses still have to be done in the flight mechanics modelisation: Based on its very rich experiences and researches programs, Eurocopter is making effort to continuously improve its simulation capacity for design needs and training simulators. Helicopter manufacturers involvement in the standards definition should continue in parallel in order to better ensure the quality of qualified simulators.

Eurocopter has proved its capacity to answer these important needs of pilots training by high level simulators usage. Efforts being done will answer the target to always improve this level of quality.

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ANNEX1

Support & Services

Royal Aeronautical Society,
Flight Simulation Group,
ICAO 9625 IWG H Steering Group

on, November 16th, 2010

Dear Steering Group Members,

As you certainly know already, our four CEOs co-signed a joint letter during HAI 2010, highlighting the need to improve the entire industry's safety practices, based on International Helicopter Safety Team (IHST) recommendations. Training is clearly identified as a major safety enabler, and IHST recognise the high value of OEMs ground and/or flight training, and also encourage usage of training in simulators.

We are convinced that the future ICAO 9625 H revision (which IWG H works started in May 2007), being based on training tasks analysis instead of technological capabilities, will result in increased simulator usages, whilst also providing worldwide harmonisation among as many Aviation Authorities as is possible.

It is our view that customers have the right to know if their training is being performed on FSTDs that contain OEM data. As OEMs, we have formed this view knowing that it is more and more complex to reverse engineer the increasingly sophisticated embarked software that many of our products already contain and that this fact is unlikely to change for the foreseeable future. We are not asking for a revision of any definitions; the concept of "preferred data sources" as currently used in ICAO, FAA and JAA, is fully supported by us. We seek simply to add clear visibility for those customers who wish to train using OEMs' Helicopter Data Pack (HDP), visibility that may be achieved by the addition of a simple watermark, logo or nomenclature like "alpha" for any H/C type specific FSTD (e.g. Type IVα).

This is normal practise in other consumer products today, for example in Personal Computers where OEMs use a simple "Intel Inside" logo to distinguish their products in the marketplace.
Furthermore, such visibility also may be of benefit to Authorities and the industry alike during FSTD qualification and investigations following aircraft incidents or accidents.
For us, the real issue is about the associated safe operations of our products, especially in learning from real incidents/accidents through replay in FSTDs, in order better to understand what went wrong and to ensure that the right lessons are learned.

In return, as OEMs, we recognise that the processes we used to follow in the creation of HDPs has further room for improvement, in order to make our HDP more cost-effective for the market, as it was the case some years ago in the fixed wing industry. However, as it has happened in the fixed wing industry, and recognising the safety implications of not fixing the cost issues associated with OEM data, we take the commitments to continue improving our HDP price so that it will not be a hindrance to the implementation of an improved safety strategy. Please note that already in today's marketplace, having OEM data inside does not necessarily mean having unaffordable training.

We hope that this proposal will be received positively and we look forward to hearing your views on this important subject.

Best regards

J. Ponsonby	D. Maldonado	D. Sharples	D. Adler
AgustaWestland	Bell	Eurocopter	Sikorsky
Training	Customer Support & Services	Support & Services	Support & Services
Senior VP	Senior VP	Executive VP	Executive VP

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