LOW-C0ST HIGH-FIDELITY FLIGHT SIMULATION –
A CONTRADICTION OR NEW OPPORTUNITIES FOR HELICOPTER PILOT TRAINING?

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Abstract

JAA Flight Crew Licensing for helicopter pilots allows a major part of the required training to be conducted on Synthetic Training Devices (STD).

Based on commercial of the shelf technology, Flight and Navigation Procedures Trainers (FNPT) or Flight Training Devices (FTD) offer effective flight training at a fraction of the operating costs of a Flight Simulator or a real Helicopter.

The ELITE evolution S623 Helicopter is such a STD. It replicates an AS 350BA Ecureil, has been certified as 'Category B Synthetic Trainer' to Australian Regulations and will subsequently be qualified as a JAR compliant FNPT.

Core of the S623H is the ELITE helicopter model, which is based on a mathematical model developed by NASA for a Sikorsky SH-3G Sea King and due to its generic character can be adopted to any other type of helicopter.

The S623 Helicopter demonstrates that low-cost high-fidelity helicopter flight simulation is not a contradiction in terms

Nevertheless, large fleet operators in the police and air ambulance segment operate light- to mid-weight twin-turbine rotorcraft and call for Multi-Crew cooperation (MCC) and type specific training.

As a consequence, Elite has developed a concept for a FNPT III MCC / Level 2 FTD focusing on the Eurocopter types EC 135 and EC 145.

Based on a network of strategic partnerships the concept places emphasis on mature technology and already existing components reducing development risk and time to market to a minimum.

Assuming, that a launch customer contract will be placed until the end of 2004, a first EC 135 / EC 145 FNPT III MCC can be completed until midyear of 2005.

To which extent training on Flight Simulators or real helicopters will be transferred to FNPT or FTD is a question, the market will answer by itself.

Motivation

Flight training of helicopter pilots in the past has been limited to real helicopters or fairly complex full Flight Simulators, with the latter seeing use only in military aviation or for type specific training on large transport helicopters. Other Synthetic Training Devices (STD) like Flight and Navigation Procedures Trainers (FNPT) or Flight Training Devices (FTD), which are by definition less complex than FS, did virtually play no significant role.

But due to the progress in computer technology, especially in the multi media field, high-fidelity simulation is no longer a matter of highly priced special equipment.

Today powerful computers and computer graphics rank among consumer goods. As a consequence, it is now possible to build high-fidelity FNPT or FTD with relatively low-cost commercial of the shelf products.

The capabilities of those modern training devices are already reflected in JAA Flight Crew Licensing. For example half of the minimum 50 flight hours for a single engine helicopter Instrument Rating (IR-SE(H)) can be done on a FNPT II (Ref 4).

Instruction can be much more efficient in a STD than in the real aircraft. Additionally, FNPT and FTD offer training at a fraction of the operating costs of a helicopter or Flight Simulator.

While training of aeroplane pilots has yet taken advantage of these benefits and the use of fixed wing FNPT and FTD gets commonplace, it is a fairly new idea to the helicopter community.

However, a change of mind can be observed. Cost saving potentials in the amount of some million Euros can not be neglected.

Additional drivers are ecological reasons, especially noise abatement, as well as the growing importance of Instrument Flight training. For example, the Swiss air ambulance operator REGA is presently developing low altitude IFR procedures (Ref 6).

Against this background low-cost high-fidelity training devices might generate there own market demand.

Regulatory framework

The Joint Aviation Requirements for Synthetic Training (JAR-STD) differentiate four categories of training devices: Flight Simulators (FS), Flight Training Devices (FTD), Flight & Navigation Procedures Trainers (FNPT) and Basic Instrument Training Devices (BITD).

Flight Simulator - FS

A Flight Simulator (FS) is *a full size replica of a specific type or make, model and series helicopter flight deck, including the assemblage of all equipment and computer programmes necessary to represent the helicopter in ground and flight operations, a visual system providing an out of the flight deck view, and a force cueing motion system*. It is in compliance with the minimum standards for Flight Simulator qualification laid down in JAR-STD 1H (Ref 1).

Four qualification levels are defined, A, B, C and D, whereas Level D demands the highest degree of reality from the simulation.

The most significant visible feature, which differs a FS from an FTD is the motion platform.

Flight Training Device - FTD

A FTD is *a full size replica of a helicopter's instruments, equipment, panels and controls in an open flight deck area or an enclosed helicopter flight deck, including the assemblage of equipment and computer software programmes necessary to represent the helicopter in ground and flight conditions to the extent of the systems installed in the device. It does not require a force cueing motion or visual system*. It is in compliance with the minimum standards for a specific FTD Level of Qualification laid down in JAR-STD 2H (Ref 2).

Three levels of helicopter FTD are distinguished. While a Level 1 FTD is meant to cater only for systems training, a Level 2 device might also be qualified as a FNPT II. A Level 3 FTD is basically a Flight Simulator without a force cueing motion system.

Flight and Navigation Procedures Trainer – FNPT

A FNPT is *a training device which represents the flight deck/cockpit environment including the assemblage of equipment and computer programmes necessary to represent a helicopter in flight conditions to the extent that the systems appear to function as in a helicopter*. It is in compliance with the minimum standards for a specific FNPT Type of Qualification laid down in JAR-STD 3H (Ref 3).

There are three levels of FNPT. While a FNPT I is only suitable for basic (instrument) flight training, a FNPT II qualifies for all non-type specific training except for landings in confined areas and on elevated heliports, which are reserved for FNPT III.

Only FNPT II or III can also qualify for Multi-Crew cooperation training (MCC).

While a FTD has to be type specific, a FNPT might be type representative, but only has match a class of helicopter and not a specific type.

Basic Instrument Training Device - BITD

A BITD is *a ground based training device which represents the student pilot's station of a class of helicopters. It may use screen based instrument panels and spring loaded flight controls, providing a training platform for at least the procedural aspects of instrument flight*.

Since neither the operators nor the manufacturers push for a helicopter BITD, there are no JAR for this category of STD at the moment.

Credits

JAR-FCL 2 defines the credits for training on helicopter STD (Ref 4). The maximum credits which can be granted for STD training are listed in Tab 1. For example, up to 30 hours of the 55 hours mandatory for a Multi Engine Instrument Rating [(IR-ME(H)] can be done on a category 2 Flight Navigation Procedure Trainer (FNPT II).

Two things get apparent, when comparing the credits for the different STD categories. First, there is no difference for non-type specific training credits between an FNPT II MCC and a FS.

Second, there are no credits given for FTD training at the moment. This gap between JAR-STD and JAR-FCL should be closed as soon as possible by the regulating bodies. Because which training organisation will invest in a FTD, when it can not be sure of the added training value?

JAR - FCL 2 Paragraph	Licence / Rating	Training item	FCL 2 Req.	FNPT I	FNPT II / III	FNPT II / III MCC	FS
2.120	PPL(H)	Basic training	45 h	5 h	5 h	5 h	5 h
2.160+165 a.1	ATP(H), Integrated	Instrument training	35 h	10 h	20 h	20 h	20 h
2.160+165 a.2	CPL(H), Integrated	Instrument training	10 h	5 h	5 h	5 h	5 h
2.160+165 a.3	CPL(H), Modular	Instrument training	10 h	5 h	5 h	5 h	5 h
2.170	CPL(H)	Skill test Section 4	No	Yes	Yes	Yes	Yes
2.185	IR(H)	Revalidation, Renewal	No	No	Yes	Yes	Yes
2.205	IR-SE(H), Modular	Instrument training	50 h	15 h	25 h	25 h	25 h
	IR-ME(H), Modular	Instrument training	55 h	20 h	30 h	30 h	30 h
2.240	Type Rating	Skill test, Proficiency check	No	No	No	No	Yes
2.261 d.1		MCC training	20 h	-/-	-/-	20 h	20 h
2.280	ATP(H)	Experience	1000 h	-/-	-/-	-/-	100 h
2.335	FI(H)	Experience	300 h	-/-	5 h	5 h	5 h
2.340		Instructor training	30 h	-/-	5 h	5 h	5 h
2.365	TRI(H)	Experience (last 12 mth)	30 h	-/-	-/-	-/-	15 h
2.370		Revalidation, Renewal	30 h	-/-	-/-	-/-	15 h
2.395	IRI(H)	Instructor training	10 h	-/-	10 h	10 h	10 h

Tab 1: Credits for STD training according to JAR-FCL2

ELITE evolution S623 Helicopter – a first approach

The ELITE evolution S623 Helicopter is Elite's first approach to satisfy the needs of helicopter Flight Training Organisation (FTO). It has been built to gather first experiences as well as first reactions from the market.

The S623 H resembles the cockpit layout and flight characteristics of an Eurocopter AS 350BA Ecureuil and features a three-channel external visual system (Fig 1).

Fig 1: ELITE evolution S623 Helicopter

A first unit has already been qualified as 'Category B Synthetic Trainer' according to Australian Civil Aviation Regulations CAR 1988 and now sees service with a New Zealand FTO.

While delivering a realistic flight simulation, the S623H is based on commercial of the shelf components and a modular and evolutionary software approach. This guarantees a cost efficient solution with state of the art technology. The different modules are described in the following.

Computing

The whole simulation runs on four conventional Personal Computers. One is the ELITE host computer, which controls and computes the whole flight- and systems-simulation including the Instructor Station. A natural choice, since the ELITE software has been designed

The three other PC's are the image generators of the visual, one for each channel. All PC's use Microsoft Windows as an operating system. The only modification compared to a standard of the shelf PC are special graphic cards to render the flight instruments and the visual scene with a sufficient update rate.

Cockpit

The shape of the cockpit hull is an exact copy of the front part taken from an AS 350BA helicopter. The hull and the floor is completely made out of composites, which is a light weighted, robust and maintenance free material. No wooden parts are used which is important for overseas export.

Avionics and Instruments

The S623H features a conventional, multi-crew cockpit (Fig 2). All instruments are displayed on integrated TFT panels, with mask overlays for buttons and turn knobs. The centre console includes 2 Nav/Com's, ADF, Transponder, DME, A/P, GPS and a special AS 350 switch panel.

Fig 2: Cockpit of the ELITE evolution S623 Helicopter

Controls and Control Loading

A bought-in set of generic, yet AS 350BA like primary controls is used. Travel ranges and stiffness match as much as possible the original ones. No control loading is present. The handgrip of the cyclic pitch has been modified to replicate that of an AS 350.

Additionally, an exact copy of the FCL control unit (fuel flow leaver, starter, fuel shut off valve and rotor brake) is integrated.

Visual System

A three-channel visual system with conventional LCD-beamers produces the outside view (Fig 1). Presently the database consists of a high resolution elevation model with generic terrain textures (ELITE GenView). All runways have realistic runway and approach light systems. For heliports a generic light system has been implemented.

Instructor Station

The Instructor Station is a modified version of the standard ELITE instructor station for fixed wing FNPT's consisting of two 15" inch TFT screens with conventional keyboard/mouse input. Modifications reflect special helicopter malfunctions like engine hot start / hung start, tail rotor loss etc.

ELITE Helicopter Flight Model

The ELITE Helicopter Flight Model is the core of the S623H and the basis for subsequent training devices. It is composed of four main modules: Aerodynamics, Aircraft Dynamics, Flight Control System and Engine Model.

Aerodynamics

The aerodynamic model of the S623 Helicopter Simulator is a complete simulation of all forces and moments, which are produced by the different components of a real helicopter.

Obviously the main rotor, tail rotor and engines are the major force and torque producing devices. But also the fuselage area of a helicopter produces recognizable forces which a good aerodynamic model should take into account.

Another very important force and moment producing device is the landing gear, whether simulating skids or tires. It is clear that these forces and torques are only evaluated during ground contact. Special treatment is required during initialisation of the aircraft on ground.

The aerodynamic model for the main and tail rotors and the fuselage are based on a mathematical model developed by NASA (Ref 5). Though the model has been developed and verified for a Sikorksy SH-3G Sea King Helicopter, due to a full generic approach, the basic aerodynamic equations can be adopted for different helicopter types. For the first implementation, the model specific parameters were changed in such a way, a Eurocopter AS 350BA can now be simulated.

Most important for the flight characteristics are the basic geometric parameters for the rotor systems, like number of blades, blade length, chord, lift and drag coefficients, and many more. Also flapping of the rotor blades is simulated, so parameters for flapping hinges are used to describe the behaviour of the rotor systems.

These parameters as a whole are good enough to model the basic flight characteristics such as maximum airspeed, climb performance and performance in autorotation. The model matches real flight test data sufficiently.

Aircraft Dynamics

A very important part in simulating a real helicopter behaviour is the aircraft dynamics simulation. These are mainly the airflow simulation, and center of gravity (CG) calculations.

Moving a helicopter through the air means a constant change in airflow velocities and directions, from which the airflow is acting on every part of a whole helicopter system. The most important results from calculating aircraft dynamics are angle of attack and angle of side slip and airspeed, as well as dynamic pressure.

CG calculation is important as well, as we want to have different load configurations and dynamic change of CG during the flight, caused by fuel decrease. This change influences the whole dynamic behaviour of a helicopter, as all forces are acting through the CG.

Flight Control System

The Flight Control System (FCS) converts the input from the primary flight controls (collective, cyclic and pedals), into longitudinal and lateral cyclic control angles of the main rotor, the collective pitch angle of the main rotor and the tail rotor.

Real travel ranges of the main flight controls had been measured and translated to according control angles for the rotor systems.

An Automatic Stabilization Equipment (ASE) is also implemented, which overrides cyclic input values to stabilize longitudinal and lateral axes. A collective ASE controls collective pitch angle to achieve a barometric hold facility. Finally a tail rotor ASE drives a direction hold device. Targeting the AS 350BA, these features are not used due to the missing ASE equipment in that specific helicopter type.

Engine Model

The Engine Model simulates a typical helicopter turbine power plant with specializations which reflect the AS 350BA type specific engine dynamic and power output.

During normal flight conditions, the engine is governed to keep the main rotor RPM in it's normal operation limits. The governor model is implemented with typical lag in reaction, so that over-torque conditions with massive drop in rotor RPM are also covered.

Besides the normal governed flight, the engine torque can also be controlled by manually adjusting the fuel control leaver. This enables the simulation of engine startup and shutdown. Autorotation with or without engine recovery can also be conducted.

Tuning

Since the flight model is always a simplification of the real aircraft characteristics and access to reference data may be limited, a more or less extensive tuning session is necessary at the end of the development process.

Besides the very obvious layout parameters gained through reference data, an additional set of values is used to simulate the type specific flight characteristics. These are found by extensive trial sessions in the simulator performed with experienced pilots.

This tuning is necessary due to the missing motion platform. We found out, that some behaviours had to be over exaggerated, like yaw response to torque changes. The missing g-force had to be compensated by adequate visible reaction. Also the behaviour in a hover was too difficult to control, especially very experienced pilots reported bad hover stability. The ability to hover is manly driven be feeling g-forces. The lack of a motion platform issued in an over stable behaviour during hover. One could say, that a simulator basically designed for IFR training, must not have good hover characteristic. But the first thing that a pilot does in a simulator, is trying to hover. And when he is able to hover, then he loves the simulator. That is one lesson learned.

JAR Qualification

JAR qualification of the S623 H will follow a stepwise approach. First, qualification as a FNPT I is sought. To achieve this, only minor modifications of the controls are expected if any, since CAR 1988 does not require any control loading and JAR-STD 3H only demands that "control forces and control travel shall broadly correspond to those of a helicopter" (Ref 3).

The next step will be the qualification as a FNPT II. For this, a full control loading system might be added to the present configuration. However, it has yet to be clarified, to which extent a control loading system is necessary for a helicopter which features a redundant hydraulic servo-control assistance.

Qualification as an FNPT III will than just be a matter of the deployed visual system. A solution which qualifies for category III will be presented in the next chapter.

MCC qualification is only foreseen for "*multi engine and multi pilot helicopters*" (Ref 3). Thus, this is not an option for a STD representing the single-turbine Ecureil.

Concept for a JAR FNPT III MCC / Level 2 FTD

Although, single-engine turbine helicopters of the AS 350BA class are popular with private and air taxi operators, large fleet operators in the police and air ambulance segment have focused on light- to mid-weight twin-turbine rotorcraft. In Europe the Eurocopter types EC 135 and EC 145 are dominating this market.

As a consequence Elite Simulation Solutions (ESS) has developed a concept, how to built a FNPT III MCC / Level 2 FTD representing a EC 135 or a EC 145.

Most operators order these helicopter types with Eurocopter's standardised glass cockpit, the so called "Avionique Nouvelle" (Fig 3). The commonality in avionics between the two types, justifies developing a concept for both types in parallel.

Comparing Fig 2 and Fig 3 it gets obvious at the same time, that the difference to the AS 350BA is not only in gross weight and power plant. Hence, the a EC 135 / EC 145 STD can not just be derived from the S623H.

Given that the reference data for a Level 3 FTD is the same as required for a FS and as such assumes access to original flight test data or own extensive flight tests, the concept presently has been limited to a Level 2 FTD.

Fig 3: Glass cockpit of an Eurocopter EC 145

Strategy

To keep development costs, technological risk and time to market to a minimum, by now available hard- and software will be utilised to the maximum extent.

Partnering companies have been found who will supply the main cockpit hardware, the systems simulation, the external visual and the control loading.

As a consequence, ESS provides the core flight simulation and acts as a system integrator, responsible also for marketing, sales and qualification issues.

Enabling Technologies and components

Implementation of the concept places emphasis on approved methods and mature technology.

Cockpit A cockpit hull with the shape of the EC 135 or the EC 145 front section can be made out of composites, like it has been done for the S623H. Yet, because the hull will consist for the most part of acrylic glass and the cockpit section will be enclosed by the visual system described below, it is left to discussion with the authorities, if a cockpit hull is necessary at all.

Flight Simulation The ELITE helicopter model will be adopted to an EC 135 or EC 145 respectively, like it has been described above for the AS 350BA.

Avionics and Instruments ESS has formed a strategic partnership with a supplier, who has already equipped EC 135 Flight Simulators. Therefor, replicas of the main „Avionique Nouvelle" components are available.

Simulation of on-board systems including the instrument representation will be taken from a Computer Based Training (CBT) which has been developed and delivered to the Swiss air ambulance operator REGA for the EC 145.

A proof-of-concept test merging soft- and hardware has yet been successful. Fig 4 shows a replica of a CMA 3000 FMS with EC 145 CBT software running on it.

Fig 4: Replica of a CMA-3000 FMS

Controls and Control Loading No final decision has been made on the Control Loading. Nonetheless, Elite's supplier for aeroplane control loading systems as well has a mature helicopter control loading system in its portfolio, which should at least qualify for an FNPT III MCC / FTD.

Visual System The requirements for an FNPT III call for a minimum 150° x 60° field of view. To provide a well tested yet cost effective solution, ESS has teamed up with the Fraunhofer Competence Center for Virtual Environments in Stuttgart. The so called CAVE projection, well established in virtual reality applications will be adopted for flight simulation.

A complete CAVE places the viewer in a fully enclosed virtual environment. This achieved by a six side rear projection system (Fig 5). For a FNPT III the CAVE is reduced to its front and side screens.
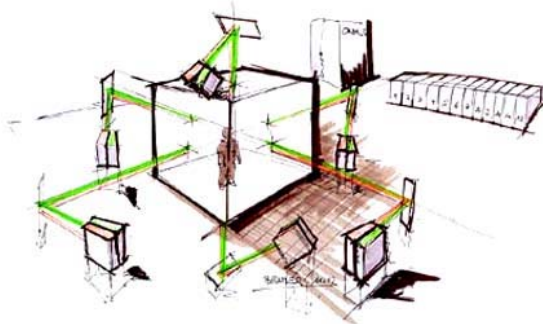

Fig 5: Concept of a back projection CAVE

The GenView software which is presently used in the S623H will be replaced by the new ELITE visual. For this ESS has formed a strategic partnership with ViewTec Ltd., a Swiss company specialised in 3D computer graphics.

The new visual will support industry standard database formats like OpenFlight or Terrex TerraPage. Terrain textures based on digital orthophotos with 2 meter resolution are possible as well as customized 3D models of cities, airport or elevated helipads. These features will allow navigation by visual landmarks, training of low altitude flight and landing in confined areas.

Conclusions

ESS has demonstrated with the ELITE evolution S623 Helicopter that high-fidelity flight simulation for helicopter pilot training base on low-cost commercial of the shelf technology is not a contradiction in terms.

The concept for a Eurocopter EC 135 / EC 145 FNPT III MCC can be implemented in a short time frame, given that it is relying on existing components. Discussions with potential launch customers are at an advanced stage and promise, that a first device sees birth in 2005.

The concept does allow additional qualification as a Level 2 FTD with minimum modifications if any, which is important in the current regulatory situation, where FTD credits still have to be defined.

To which extent training on FS or real helicopters will be transferred to less complex STD is a question, the market will answer by itself.

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