Build High fidelity simulator without data

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Picture is the Tiger simulator courtesy of DGA Flight Testing.

Introduction

Many companies face a common problem when comes time to build an aircraft simulator; either they just don't have access to the required data package or they don't have the financial resources to buy that data package. This problem occurs regardless of the simulator's purpose (training, avionics test bed, etc.) and for both fixed-wing aircraft and helicopters. In such cases, they are left looking for alternatives and to figure out what is the best level of fidelity they can expect given their available budget. In addition, they have to determine the impact on the certification or qualification level of their new simulator.

Clarification

Before going any further, a clarification should be made between the use of terms certification and qualification in simulation since they don't necessary have the same meaning when used in civilian or military world.

As a matter of fact, the term certification is usually restricted to the civilian world and only when referring to training applications. The certification level indicates the fidelity level of the application and is associated to the type of simulator (for instance a Full Flight Simulator (FFS) of level D, a Flight Training Device (FTD) of level 5, a Flight & Navigation Procedures Trainer (FNPT) of level II, etc.).

For its part, the term qualification is used in both civilian and military worlds but don't always have the same meaning. In both worlds, qualification refers to successfully proving that a system meets its requirements. However the difference resides in what the term system refers to. In the civilian world, it is restricted only to the tools that are used to certify the simulator and not to the simulator itself. On the other hand, in the military world, it can be applied to both the tools and the simulator.

How to get a high fidelity simulator?

The obvious answer to that question is by getting the necessary data package either directly from the aircraft manufacturer (which can be very expensive) or by building it by instrumenting the actual aircraft (which is also expensive and time consuming).

On the other hand, not having a data package does not automatically mean that a high fidelity simulator cannot be built. However, the level of fidelity of the simulator will be directly linked the financial budget allocated to its development. That being said, the following questions should be answered in order to control the costs and this even before the start of the development of the simulator:

1. Expectations: What is the purpose of the simulator? How will it be used? (Very often a simulator is built for a level of fidelity that exceeds what is really needed which increases the cost of the simulator for nothing).

2. Hardware: What hardware components (from computers to image generator, sound generator, pilot inputs devices, control loader, etc.) are needed? Who is responsible for their integration? (Again hardware selection should be aligned with the expectations).
3. Software: What software components are needed and who is responsible for their integration? (Should be aligned with the hardware requirements).
4. Data: Even though a complete data package is not available, what information is or will be available about the aircraft to simulate?
5. Time: What is the time frame in which the simulator must be delivered?
6. Money: What is the financial budget available for the project? (Even though the previous questions must be answered to better control the cost, the reality is that the amount of money available will have an impact on the answers which means that the overall expectations might be reduced).

One thing that is important to keep in mind is that a minimum quantity of information is mandatory. That information can be broken in 2 parts; physical data and performance data.

The physical data includes information related to the physical characteristics of the aircraft like for instance:

- Aircraft Mass
- Moments of Inertia
- All control surfaces characteristics
- All aerodynamic Surface definition (minimum is the geometry)
- Number of engine
- Power Turbine (PT) Rotation Per Minute(RPM) for helicopter, N (Net thrust) for aircraft
- If Fly-By-Wire (FBW) (need some Automatic Flight Control System (AFCS) description)

The performance data includes information necessary to compare the flying behavior of the simulated aircraft with respect to the real one like for instance:

- Operational Manual, or/and
- Flight Manual, or/and
- Performance curves (climb/descent rate, Vr (rotate speed), V1 (takeoff decision speed), V2 (takeoff speed), Cruise speed, stall speed, etc.), or/and
- Performance engine data, or/and
- Specific tests results data, or/and
- Etc.

Note that pilots can be used in order to compensate missing parts of the above mandatory information. Furthermore, pilots can be used to increase the fidelity level of the simulator.

Tiger project

A good example on how a high fidelity simulator can be built without having the necessary data package is the Tiger project. This project consisted in building a simulator, with qualification, of a Tiger attack helicopter for the Direction General de l'armement Flight Testing group of the French government. For this project, 3 companies joined their efforts with Oktal acting as the prime contractor while Presagis and RAAS were sub-contractors.

Presagis's HeliSIM product was used as the core software for the helicopter modelization of the simulator and RAAS was responsible for the development of a helicopter model corresponding to the Tiger in HeliSIM. All integration aspects, both software and hardware, for the simulator (including SAGESSE (core software), visual system, cockpit instruments, control loader, etc.) were the responsibility of Oktal and DGA Flight Testing.

For this specific project, accessibility to the data was the main issue and it was mainly for proprietary reasons which had for consequences that the data package available for this project was missing some key information like for instance:

- No aerodynamic data characterizing the helicopter (including fuselage, winglets, horizontal stabilizer and vertical tail)
- No AFCS control laws
- No aerodynamic data characterizing the blade of the main rotor
- No physical characteristics of the main rotor's blade with the exception of its length
- No engine data at all
- No landing gear data

As a matter of facts, the only information available was:

- Flight manual
- Video of the Multi Function Display (MFD) during flight
- General specification and performance of the helicopter
- Requirements documents dating prior to the development of the helicopter meaning that there are no guarantees that they described the implementation found in the current helicopter

Furthermore, information was also lacking in order to qualify the simulator. The usual way of qualifying a simulator consists in performing the same tests in the simulator as in the real helicopter, collecting data and comparing the behaviors. Since no flight test data was available(again no access to data for proprietary reasons) for the real helicopter then the qualification approach was changed and was based on what is done for evaluating handling qualities of real helicopters according to the AERONAUTICAL DESIGN STANDARD PERFORMANCE SPECIFICATION HANDLING QUALITIES REQUIREMENTS FOR MILITARY ROTORCRAFT (ADS-33E-PRF). Therefore the Cooper-Harper method consisting on a subjective ranking by pilots of the handling qualities of the simulator for a series of specific tests was used. The goal of using ADS-33 is to help the test pilot to compare the behavior of the simulator to the reel helicopter (Tigre).

The first step taken by RAAS in order to resolve the problem of missing data was to take advantage of the fact that some helicopter models are distributed with HeliSIM. Therefore, the first version of the Tiger model was built by putting together information coming from existing models and by adjusting them to better represent a Tiger helicopter. As it can be expected, this approach has its limitations since not all the required components can be found in the provided models. Therefore, the next step was for RAAS, with the help of Presagis, to construct the missing information by using either some analytical methods (like for generating the aerodynamic impact of the winglets) or by using their expertise (mainly in the development of control laws of the AFCS). The next step was a rather complex tuning session for RAAS which consisted in adjusting parameters to match the few available performance data by trials and errors.

Since as mentioned before the qualification of the simulator was based on the ADS-33, the next step was to tune the model while performing the maneuvers described in that document. Once these requirements were met, there was a final tuning session which had a real Tiger pilot flying the simulator for reproducing these maneuvers. This approach is very beneficial when doing a qualification based on the Cooper-Harper method since it guarantees that at least one pilot is already satisfied with the simulator before bringing in more pilots for their evaluations.

It must be kept in mind though that for qualifying successfully the simulator using the Cooper-Harper method, pilots must be properly prepared before stepping in the simulator for their evaluations. That preparation consists mainly in making sure that their expectations match the level of fidelity required for the simulator. I have notice by experience that pilot over estimate the aircraft performance, sometime it is very useful that pilot go back in the reel aircraft to perform some of the ADS-33 tests. In this project, the pilot used flight test feedback methodology base on flight test doctrine. Pilots will always find something in the simulator that is not behaving exactly as in the real helicopter but it might not necessarily by an issue in the context in which the simulator will be used. In the present case the simulator is not used for training but rather as a simulator for aircraft development. This simulator is considered by DGA Flight Testing as a prototype of a Tiger because is not a full dynamic representation but is close enough for the pilot to fly the simulator without any compensation allowing him to focus of the specific task (for example: human factor feedbacks for displays ergonomic).

During that project, RAAS has developed a methodology to build, calibrate and test the aircraft model. That methodology reduces parameterization, calibration and testing duration of the project. Also, RAAS has developed a method to instrument the model (strategic parameters that can be tuned to correct dynamic respond) to perform live calibration with the pilot, to maximize the effectiveness of the time spent in the simulator.

For more information on how to build, qualify and/or certify a fixed-wing and/or helicopter simulator using Presagis's FlightSIM and HeliSIM products, contact:

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