

DATA PACKAGE REQUIREMENTS FOR DESIGN AND PERFORMANCE EVALUATION OF ROTARY WING SYNTHETIC TRAINING DEVICES

Steve Adlem, Chairman of Data Package Requirements For Design And Performance Evaluation Of Rotary Wing Synthetic Training Devices Working Group, Royal Aeronautical Society, UK

1. Abstract

Safe helicopter operations are underpinned by training. Safe and effective training can be conducted on the ground using synthetic training devices. The use of such devices including flight simulators is a growth area in helicopter pilot training and their qualification has been formalised through defined standards by leading regulatory bodies. Synthetic training device development and qualification processes are dependent on access to accurate platform design, performance and systems data. The requirements for suitable data must be established at the acquisition phase.

The fixed wing world has for many years relied on a data package requirements document published by IATA for authoritative guidance. There has been no rotary wing equivalent until a recent initiative led by the Royal Aeronautical Society Flight Simulation Group (FSG) to describe data package requirements specifically for the design and performance evaluation of rotary wing synthetic training devices.

The working group tasked by the FSG included representatives from the simulator and platform manufacturers well versed in the modelling of demanding helicopter simulations and the need to deliver validated modelling to support training and regulatory needs. Consideration was given to topics including the cost of data collection and the provision of validated models in place of raw data.

Working Group members were drawn from the UK CAA, the French DGAC, the UK Ministry of Defence, Eurocopter, Westland Helicopters, EADS Dornier, SEOS, Evans & Sutherland, Kohlman Systems Research, University of Liverpool, CAE, Sogitec, and Thales Training & Simulation.

The published document provides guidance to the whole community involved in these activities including helicopter and training operators, helicopter and avionics manufacturers, simulator and training

device manufacturers, government procurement agencies and regulatory bodies.

This paper describes the development process and outlines the document content. The data requirements document is already in use in UK MoD procurement, and the paper concludes by setting out the very real and tangible benefits that can be realised by its wider use across the industry.

2. The Need for Definition of Data Requirements

In recent years, a number of regulatory documents have been published to support the qualification of rotary wing flight simulators and training devices. However to develop a device that will move successfully through the validation and verification processes of regulatory qualification requires access to suitable platform specific data. These data will include that required to form the basis of both the implemented simulation models and the data set that will be used to confirm that the performance of the devices mimics the aircraft type within the stipulated tolerances.

A number of parties are involved in the process, including;

- Helicopter and Training School Operators
- Helicopter Manufacturers
- Avionics Manufacturers
- Simulator Manufacturers
- Regulators

The end customer, i.e. the helicopter operator whose need is training, will not necessarily be familiar with the process of purchasing either pilot training or a training device. The helicopter operator who follows this route will soon become aware that the training programme he wishes to implement, and in turn the training device or devices it is based on, will require qualification by his national regulator. Simulator manufacturers have a range of skills and experience to support the process, but the operator may wish to find a source of sound and impartial guidance as the programme is initiated, most likely

prior to the selection of the training device supplier.

2.1. Accepting the challenge

In the 1990s the Royal Aeronautical Society Flight Simulation Group responded to the call for a data requirements guidance document to be developed to service the needs of fixed wing operators. This effort produced a document that subsequently evolved into the International Air Transport Association (IATA) document, Flight Simulator Design and Performance Data Requirements, now in its 6th Edition.

The IATA document has been accepted as the industry standard definition of data requirements to meet the needs of simulator manufacturers, airline operators and platform manufacturers to have a common and unbiased statement of data needs. Indeed the document has been used as general guidance for rotary wing needs when no dedicated document has been available.

Following a clear statement of need from participants in a specialist conference addressing rotary wing flight simulation, The Royal Aeronautical Society Flight Simulation Group again accepted the challenge to form a working group and established what is hoped will become the industry standard reference work for rotary wing training device development.

The working group was formed in July 2002 with participants from major helicopter manufacturers, simulator manufacturers, specialist flight test data gatherers and the regulatory community.

2.2. The Process

To speed the development process support was sought from IATA who allowed access to the 6th Edition of their document for the working group purposes. Using a consistent documents structure a draft document was outlined by assigned rapporteurs. The final draft was completed in May of 2003 and this document was issued for comment to the rotary wing simulation community in June 2003 at the Royal Aeronautical Society Flight Simulation Group Spring Conference.

Comments received by the October deadline were incorporated

2.3. Initial Release

No clear champion of the rotary wing operators appears to have the equivalent mandate of IATA. Subsequently the Royal Aeronautical Society has taken the step of becoming the publisher of the Data Package Requirements For Design And Performance Evaluation Of Rotary Wing Synthetic Training Devices document to ensure its immediate availability to the rotary wing training community.

The current issue, Issue 1, was published by the RAeS in July of 2004. Ownership by the rotary wing operator community is desirable in for the long term, be it actual or de facto and participation will be sought from operators in the development of subsequent issues of the document.

3. The Data Needs for Flight Simulation and Systems Modelling

The document provides support to all parties in stating their requirements for data and confirming when those requirements have been met in the acquisition, development and operation of Flight Simulators and Training Devices and their validation and regulatory qualification processes.

Specifically the document is designed as a guide for:

- Helicopter Simulator Operators and procurement organisations to support a standardised approach to the Data Package acquisition process
- Helicopter Manufacturers and Vendors of Helicopter Equipment to define the expected scope and content of helicopter/system Data Package necessary to build simulators of adequate fidelity for modern crew training and simulation
- Helicopter Simulator Manufacturers, when working with Helicopter Manufacturers and vendors and procurers

3.1. Applicability, Training Devices and Regulatory Approvals

The scope of the document is to support the acquisition of the full range of training devices currently defined and implemented by manufacturers and operators and as defined by the various regulatory bodies. The data identified in their fullest definition corresponds to the data requirements to develop an approved civil helicopter Full Flight Simulator (FFS) of the highest qualification level, or a military Full Mission Simulator (FMS) designed for aircrew training to qualified on type or operational aircrew standards. The document is intended for use as a "check-list" for these FFS/FMS data requirements but also for other types of Synthetic Training Devices, which require a Data Package of a reduced scope.

However, the document has broad application presenting a generic aspect, covering both a large range of civil and military helicopter types and helicopter equipment items, and the full range of simulation devices and data format (papers, software models, use of actual equipment). For each specific application, it will be necessary to tailor the document to the simulated helicopter / STD configurations. Different simulation approaches may also lead to different data package content, keeping in mind, however, that even when full models are provided, necessary material will have to be provided to give simulator manufacturer and Authorities the ability to check model performances against an approved reference.

The different civil and military helicopter types considered in this document are passenger and utility helicopter, mission helicopter (including attack, SAR, ASW, and ASSW) and training helicopter. Where other aircraft configurations have not been included, e.g., tilt rotor aircraft, it is recommended that their characteristics should be tackled by tailoring the document to the particular aircraft, retaining the spirit of the document.

Training simulation objectives include man-in-the-loop interactions, involving cockpit actions by the aircrew (pilot, co-pilot, weapon system officer, navigator, gunner, tactical operator).

Devices, which can readily be supported by the data defined in the document, are typified by the following categories:

- Full Flight Simulator (FFS) with FAA/JAA Type Flight Qualification Level which includes a full size replica of a specific type, model and series aircraft cockpit with aircraft, systems and environmental simulation designed to meet the qualification level.
- Full Mission Simulator (FMS), a full size replica of a specific type, model and series military helicopter cockpit, as above but including the incorporated mission systems of the platform and extended simulations to support the sensors and tactical environments, optionally it may comply with the minimum standards for FAA/JAA Qualification.
- Navigation & Weapon Systems Trainer (NWS), a full size replica of aircraft instruments, panels, equipment and controls, in an open cockpit area, with limited simulation of basic aircraft systems.
- Flight Training Device (FTD), a full size replica of aircraft instruments, panels, equipment, controls, in an open cockpit area to comply with the minimum standards for FAA/JAA FTD Qualification.
- Cockpit Procedure Trainer (CPT), a full size replica of aircraft instruments, panels, equipment and controls, in an open cockpit area, no visual or motion cueing systems are required.
- Flight & Navigation Procedure Trainer (FNPT)A training device which represents the flight deck/cockpit environment including the complement of equipment and computer programs necessary to represent a helicopter in flight conditions, such devices are generic devices not requiring a full data package. Qualification mandates the use of generic data only to check Correct Trend and Magnitude of main parameters variations.
- Computer Based Training (CBT), training software implemented on personal computer or workstation

allowing self-training of aircraft system knowledge, operation and use. There is no cockpit replica but the system may be extended to include some aircraft system emulations and inceptors.

3.2. Data Types

The data required to support the design, development and testing of the training device type noted are categorised in the document as:

- 1) Configuration/design data,
 - 2) Simulation modelling data,
 - 3) Verification data,
 - 4) Qualification data.
- Configuration and/or design data are defined as those which allow a simulator manufacturer to design and manufacture replicas of aircraft structure and components in order to construct authentic duplicates of cockpit and equipment zones of the aircraft. Data in this category also supports the design and manufacture of simulator instruments, avionics and ancillary equipment such as autopilot, INS, etc., either based on the use of unmodified aircraft equipment in the simulator or by means of simulation models of equipment functions.
 - Simulation modelling data is that contained in technical documentation specially created by the aircraft manufacturer or system manufacturer or data gathering third parties to define the mathematical construction of real-time simulations of the aircraft aerodynamic characteristics and performance of various aircraft systems, together with the numerical data to support them. The data requirements document allows that all or part of simulation modelling data can be provided in the format of software models as a substitute to the delivery of design data. This approach is favoured by certain platform manufacturers. If simulation models are provided the document notes that their implementation is required to produce stable, continuous, real-time, dynamic responses at typical training simulator iteration rates, and must be used to produce the verification data defined below.

- The verification data are required to verify correct implementation of the real-time models and as a resource for comparison between simulator and the aircraft, during simulation development. Those data can come from the aircraft manufacturer engineering simulation, wind tunnel, flight test data, measurements made on the aircraft systems, aircraft qualification procedures, etc. Such data are also often referred to as check-out data.
- The qualification data are required to verify simulation by comparison between simulator and the aircraft, for the formal simulator qualification procedure.

4. Aircraft Definition

The ensure that the applicability of any helicopter simulation to the pilot training delivered using the training device the data provided for platform and systems simulation is required to be referenced to a given aircraft and its configuration. The reference aircraft should be described using a basic configuration completed by additional equipment leading to the configuration necessary for the intended training.

The document recommends that in the case where the training device development starts after the beginning of the in-service phase of the aircraft the reference aircraft should be defined based on a tail number, engine number and a list of installed equipment and its revision level. This reference aircraft should then be used for data acquisition of flight performance data including sound, vibration and control loading data as required by the model developer and qualification authority.

The process can be more complex when training device development and aircraft development are parallel processes in order to have both systems in operation at the same time. Definition of the reference aircraft may in this case limited to the configuration described in the acquisition contract (i.e. first serial aircraft delivered). In order to follow up the aircraft development the document recommends that the reference aircraft configuration should be described at

system level with the configuration split into vehicle (structure, performance, rotor, engine, etc.) and equipment (HW, SW) including the Human Machine Interfaces.

Design data may be taken from different sources including:

- Specifications
- Equipment prototypes
- Wind tunnel models
- Integration test benches
- Helicopter prototype

The document recommends these data should be used for the initial simulator design. Due to the evolution of the aircraft development, regular updates of design data will be necessary until the aircraft design configuration is frozen. Further updates will be necessary taking into account the final configuration, functionality and performance of the reference aircraft at the date of delivery.

Fidelity of validation data for the qualification of the simulator is required to be confirmed by the aircraft manufacturer, all data provided for validation should be consistent, coherent and representative of the reference aircraft.

5. Outline of the data requirements identified

To provide some clarity regarding the scope of the data required in the development of complex training devices some detail is provided below of the types of data and data topics included in the document, and some indication of the modelling that is supported by that data. This abbreviated section will be no substitute for detailed examination of the full data package description provided by the document.

Configuration/Design Data requirements for the particular aircraft configuration are identified, including physically simulated air vehicle components, such as the cockpit structure, controls and panels, data may be required to replicate air vehicle parts or integrate actual aircraft parts into the simulator.

Helicopter Design Data requirements are identified, including geometry, dimensions and the detailed arrangements, of the helicopter, including Main Rotor and Tail Rotor, Fuselage, Empennage, Vertical Fin And Horizontal Stabiliser Aerodynamic

Requirements for coefficients and data relating to the mechanisms and arrangement for external loads are identified, as are data to support Out-of-the Window Visual Simulation, including:

- Crew Eye Reference Point(s)
- Crew Field of View Diagrams
- External Lighting Patterns

Data requirements relating to aerodynamics characteristics are identified. The helicopter manufacturer will be tasked to provide an aerodynamic model satisfying the level of fidelity required for certification according to the applicable regulatory document. The parameters of this model will include such as the Interference Coefficients of the Main Rotor on the and on the Horizontal Stabiliser. Data will also be required to model Main and Tail Rotor inflow constituents, external payload and external store aerodynamic coefficients.

Data requirements are identified addressing Helicopter Aerodynamics and flight controls qualification data, too cover both Main and Tail Rotor and Secondary Controls and including data from ground tests, in-flight tests and flight controls verification data.

Data provided must include data to support helicopter weight, cg and inertia modelling data verification/qualification data, ground handling characteristics modelling, the modelling of the landing gear system, brake system, steering system, shock strut and tyres and any relevant data for shipdeck landing.

Data requirements are defined to model engines, transmission and rotor drive systems, including operational envelope, main engine design data, engine electronic control, fuel control, oil system, air intake, transmission system. The document recommends that Full Authority Digital Engine Control (FADEC) data should where possible be provided as a software model.

Engine verification data is required and must include steady-state data and time histories. Environmental system data requirements are identified and will include data for any pneumatic anti-ice systems and electrical ice protection systems. Aircraft system data should include data to model the hydraulic system, electrical

power system and miscellaneous systems such as, auxiliary power unit, lighting, fire, smoke and overheat warning system, and other warning systems, sling load, winch, and floatation gear.

The sound, vibration and motion cues of helicopter operation are closely related and environmental cueing data is required for all sounds, motion and vibrations heard or felt within the cockpit and which are significant to flight. Vibration parameters are required for each of the following conditions as perceived in the cockpit. Data needs to be presented as linear acceleration time histories for motion cues and spectral analysis data for steady-state vibrations. Data provided should specify vibration amplitude versus speed relationships. Data describing the following effects are required:

- Terrain or runway rumble for different surfaces,
- Environmental effects of turbulence, rough air, gusts, etc.,
- Main rotor vibration characteristics,
- Tail rotor vibration characteristics,
- Main rotor out-of-balance characteristics,
- Tail rotor out-of-balance characteristics,
- Clutch engagement and disengagement,
- Engine and transmission vibrations,
- High speed buffet,
- Final approach buffeting,
- Rotor engagement phenomenon,
- G-buffet,
- Vortex ring state buffet,
- Buffet during transition from hover to forward flight and vice versa,
- Ground resonance during rotor run-up,
- Vibrations and motion cues induced by weapon release and firing (if applicable),
- Any other vibration and particular motion cue sources that are perceivable by the crew.

Aircraft and avionics systems data is required to support the modelling of;

- Flight Instruments and Air Data Systems
- Attitude and heading reference systems and air data systems
- Instrument panel electronic displays
- Navigation Systems
- Digital Data Buses

- Digital Map Generator
- Data Transfer System
- Voice Recognition
- Optronic sensor systems
- Radar Modelling And Radar Display System
- Visionics including, Head-Up Display (HUD) and Night Vision Goggles (NVG), Head-Mounted Display System, Direct View Optics
- Electronic And Automatic Flight Control Systems

Natural environment data is required to support the generation of synthetic imagery for the training device, including the out-of-the-window visual image. Radar and optical sensor simulation is typically implemented in a software model that uses environmental database techniques. Typically, these sensor simulation techniques support correlation of the sensor image with simulated out-of-the-window imagery. The common data requirements include data relating to the following:

- Terrain
- Airports
- Superstructures Of Airports and 3D Objects
- Cartography

Where sensors are implemented in the training device the data requirements must identify the need for multi-spectral data to include materials coding for the sensor image.

6. Vendor Data

Vendor data are data from aircraft equipment manufacturers as required to supplement the aircraft manufacturer data. Vendor data particularly includes data and documentation for instruments and programmable devices such as Flight Management Computers and Mission Computers.

The data requirements document advises that provision is made in agreement between aircraft manufacturer and equipment vendors to provide suitable simulator compatible software for aircraft computers used in simulators.

The document recommends that such provisions should be as defined in the ARINC 610A Guidance Report and its revisions. Description of the expected

response of hardware to the ARINC 610A Guidance Report, and its revisions, regarding the defined simulator functions is required along with activation and communication protocols.

Adherence to the ARINC 610A guidance will enhance the integration possibilities and minimise the costs of implementing aircraft hardware or software into the flight training devices that will accompany the platform into service. Typically, compliant systems will require a reduced data set to support the integration, extending the benefits to the Vendor where there are concerns regarding the protection of intellectual property rights.

When a flight simulator program is concurrent with the actual aircraft development and test program, provision must be included in agreements between aircraft manufacturer and equipment vendors to provide an avionics and programmable devices development schedule. This schedule should show the revision level of all avionics and programmable devices against the aircraft workplan. Expected certification dates should also be shown with their relationship to the aircraft certification plan.

The schedule should also allow the simulator manufacturer to establish the relationship between the different avionics and programmable device revision levels and their corresponding data revisions. In addition, during development and testing of a new aircraft's avionics and programmable devices, the aircraft manufacturer will need to supply a reference tracker document, that describes existing functionality and known deficiencies and contains information as to when and on which S/W or H/W load these problems will be corrected.

The data requirements document identifies particular requirements for the use of Vendor Software Products to support the simulation of aircraft avionics systems. A particular recommendation is for the simulator manufacturer to be provided with access to all documentation necessary to replicate the board level support environment in hardware or software, covering vendor hardware and firmware functional specifications, that will enable either:

- The re-targeting of vendor avionic software code (i.e., the use of vendor source re-compiled for a different computing platform in a simulated environment).

or:

- The re-hosting of vendor avionic software code (i.e., the use of vendor unmodified executable code running in a different computing platform in a simulated environment).

The documentation provided is recommended to include source, object and executable code of the operating system and the application layers, load maps and data files required to regenerate the executable load.

6.1. System Malfunction Data

The document further identifies that simulation modelling data should support the inclusion in the training device of a selection of malfunctions selectable by the instructor or the simulator operator. The malfunctions included in any training device should be realistic for the system as built for the aircraft. Flight test validation of malfunctions may not always be necessary and, in some cases, inadvisable or dangerous.

Malfunction modelling has a strong impact on modelling solutions, due to the extension of the simulation envelope, including degraded or back-up modes, needs for more precise algorithms, excluding global approach, and for more verification/qualification data and simulator tests.

For training simulation, malfunction choice should be based on the following criteria:

- Different visible effects in the cockpit or through physical cues,
- Different procedures; different malfunctions leading to the same procedure, could be simulated by only one malfunction,

Coverage of abnormal and emergency procedures in the aircraft Flight Manual and Operations Manual.

7. Conclusion

A clear and complete definition of data requirements for rotary wing flight simulation and training device development have been collated into a single document developed by an expert working group in the fields of helicopter manufacture and simulator manufacture, flight data gathering and simulator regulatory qualification. The benefits of this single statement of data needs accrue to all relevant parties. Perspectives may vary, but the key benefits are:

Rotary Wing Training Device Operator

- A mechanism to assist in the development of an effective simulation of a rotary wing platform and its systems, that provides a sound basis for the development of simulator performance in line with regulatory requirements.

Contracting Organisation

- A mechanism to ensure all participating parties review and agree the data requirements with minimal ambiguity as part of the contract negotiation process.

Rotary Wing Platform Manufacturer

- A clearly set expectation for data provision for training devices, that will support the planning of flight test programmes and data package compilation

Flight Simulator and Training Device Manufacturer

- A single and impartial statement of need which provides coherent guidance to helicopter simulator customers and helicopter manufacturers in the provision of data designed to support the design, development and qualification of helicopter training devices.

Reference 1

Data Package Requirements For Design And Performance Evaluation Of Rotary Wing Synthetic Training Devices, Published by the Royal Aeronautical Society, July 2004, ISBN xxxxxxxxxx, web site; <http://www.raes.org>

Reference 2

International Air Transport Association (IATA) fixed wing data requirements document, Flight Simulator Design and Performance Data Requirements, 6th Edition, 2000