



Practises to identify and prevent adverse aircraft-and-rotorcraft-pilot couplings—A ground simulator perspective[☆]



Marilena D. Pavel ^{a,*}, Michael Jump ^b, Pierangelo Maserati ^c, Larisa Zaichik ^d,
Binh Dang-Vu ^e, Hafid Smaili ^f, Giuseppe Quaranta ^c, Olaf Stroosma ^a, Deniz Yilmaz ^a,
Michael Johnes ^d, Massimmo Gennaretti ^g, Achim Ionita ^h

^a Delft University of Technology, Kluyverweg 1, 2629HS Delft, The Netherlands

^b University of Liverpool, Brownlow Hill, L69 3GH Liverpool, England

^c Politecnico di Milano, Via La Masa 34, I-20156 Milano, Italy

^d TsAGI, Zhukovsky Str., 140180 Zhukovsky, Russian Federation

^e ONERA, Base Aerienne 701, FR-13661 Salon de Provence, France

^f NLR, Anthony Fokkerweg 2, NL-1059 CM Amsterdam, The Netherlands

^g Università Roma Tre, Via della Vasca Navale 79, I-00146 Roma, Italy

^h STRAERO, B-dul Iuliu Maniu 220, Bucharest, Romania

ARTICLE INFO

Article history:

Received 27 November 2014

Received in revised form

23 June 2015

Accepted 25 June 2015

Available online 22 July 2015

Keywords:

Aircraft Pilot Couplings
(APC)

Rotorcraft Pilot Couplings (RPC)

Pilot Induced Oscillations (PIO)

Pilot Assisted Oscillations (PAO)

Simulator Fidelity

Motion Cues

Visual Cues

Control Loading

Time delay

Latency

Biodynamic Feedthrough

ABSTRACT

The aviation community relies heavily on flight simulators as a fundamental tool for research, pilot training and development of any new aircraft design. The goal of the present paper is to provide a review on how effective ground simulation is as an assessment tool for unmasking adverse Aircraft-and-Rotorcraft Pilot Couplings (APC/RPC). Although it is generally believed that simulators are not reliable in revealing the existence of A/RPC tendencies, the paper demonstrates that a proper selection of high-gain tasks combined with appropriate motion and visual cueing can reveal negative features of a particular aircraft that may lead to A/RPC. The paper discusses new methods for real-time A/RPC detection that can be used as a tool for unmasking adverse A/RPC. Although flight simulators will not achieve the level of reality of in-flight testing, exposing A/RPC tendencies in the simulator may be the only convenient safe place to evaluate the wide range of conditions that could produce hazardous A/RPC events.

© 2015 Elsevier Ltd. All rights reserved.

Contents

1. Introduction.....	55
----------------------	----

Abbreviations: AD, Acceleration Deceleration Manoeuvre; A/RPCs, Aircraft-and-Rotorcraft-Pilot Couplings; APC, Adverse Pilot Couplings Rating Scale; ARISTOTEL, Aircraft and Rotorcraft Pilot Couplings – Tools and Techniques for Alleviation and Detection; BAT, Boundary Avoidance Tracking; BDFT, Biodynamic Feedthrough; DC, Duty Cycle Criterion; DOF, Degree of Freedom; FBW, Fly-by-Wire; FCS, Flight Control System; FoV, Field of View; GRACE, Generic Research Aircraft Cockpit Environment simulator at NLR; HQs, Handling Qualities; HQR, Handling Qualities Rating; HFR, HELIFLIGHT-R Simulator at University of Liverpool; MCR, Motion Cue Rating Scale; MTE, Mission Task Element; PAC, Phase Aggression Criterion; PH, Precision Hover; PIO/PAO, Pilot Induced Oscillations/ Pilot Assisted Oscillations; PIOR, PIO Rating; PR, Pilot Rating; ΔPR, Pilot rating worsening; PVS, Pilot-Vehicle System; ROVER, Real-time Oscillation Verifier; RS, Roll Step Manoeuvre; SFR, Simulator Fidelity Rating Scale; SRS, Simona Research Simulator at TU Delft; UCE, Usable Cue Environment; VCR, Visual Cue Rating; VM, Vertical Manoeuvre; VMS, Vertical Motion Simulator at NASA Ames; ZFTT, Zero Flight Time Training

*Fitting the simulator to the task is key to getting meaningful results.' (Col. Richard Borowski, Wright-Patterson Air Force Base)

* Corresponding author. Tel.: +31 15 2785374.

E-mail address: m.d.pavel@tudelft.nl (M.D. Pavel).

1.1. Flight simulators: ideal devices for training and research.....	55
1.2. Flight simulator fidelity.....	56
1.3. Aircraft/rotorcraft pilot couplings	57
1.4. Can ground-based simulators reveal the existence of adverse A/RPC?.....	58
2. Simulator characteristics relevant to the A/RPC problem	59
3. Simulator motion system characteristics	61
3.1. Quantitative motion cueing criteria	62
3.2. Rigid body RPC motion tuning	63
3.3. Aeroelastic APC motion tuning	67
4. Simulator visual system characteristics	67
5. Simulator control loading characteristics	69
5.1. Control loading analysis in fixed wing aircraft.....	69
6. Simulator mathematical model characteristics	72
7. Selection of flight tasks exposing A/RPC tendencies in the simulator.....	73
7.1. Selection of flight tasks for exposing APC in the simulator.....	73
7.2. The Adverse Pilot Couplings Rating (APC) scale.....	74
7.3. Selection of flight tasks for exposing RPC in the simulator.....	77
7.4. Phase Aggression Criterion (PAC) as a measure of A/RPC tendencies in simulator testing	78
8. Simulator latency characteristics	80
9. Conclusions	81
Acknowledgements	82
Appendix A. 1 Motion Fidelity rating scale	82
Appendix A. 2 Visual Cue Rating	83
Appendix A. 3 Simulation Fidelity Rating scale (SFR)	83
Appendix A. 4 Traditional PIO rating scale (PIOR)	84
Appendix A. 5 Adverse Pilot Coupling APC rating scale (APC).....	85
References	85

1. Introduction

The aviation community relies heavily on flight simulators as a fundamental tool for research, pilot training and new aircraft design development. In the broadest sense, a flight simulator may be defined as a device capable of synthetically replicating the behaviour of the simulated aircraft to as high a standard or fidelity as its component parts will allow. Typically, flight simulators are used during the development of an aircraft, to conduct basic aeronautical vehicle or systems research or as a means to train pilots and crew. This paper provides the most up-to-date research on the former of these, specifically the use of flight simulators to unmask a phenomenon known as adverse aircraft/rotorcraft pilot coupling. However, to set this work in its wider context, a very brief review of flight simulation being used for training is also presented.

1.1. Flight simulators: ideal devices for training and research

The flight simulator, as would be recognised by modern engineers, was invented in 1931 by Ed Link [1] to be used as a pilot training device. However, as early as 1910, the need for simulators was recognised to familiarise the pioneer pilots with the control characteristics of aircraft of the day. The first recorded flight simulator was the "Antoinette Learning Barrel", shown in Fig. 1. In this flight training device a pilot was required to use the controls to keep a horizontal reference bar aligned with the horizon as the barrels were moved by human operators to represent pitch, roll and yaw.

For training purposes, flight simulators can range from low-cost procedural trainers to high fidelity, high-cost simulators. From these early beginnings, pilots now conduct a significant part of both their initial and recurrent training through the use of simulated flying time. For example, Fig. 2 shows the HELISIM facility [34] specially dedicated to helicopter pilot training at Eurocopter (now Airbus Helicopters) in France with certified

Level D simulators¹. The advantages of such training flight simulators are recognised and most modern flying organisations, both civil and military, use such devices. In 2006, the International Civil Aviation Organisation (ICAO) launched the Multi-crew Pilot License (MPL) which was designed to drastically reduce the number of real flight training hours required to reach the first-officer seat of a fixed wing airliner compared to the more traditional Air Transport Pilot's License (ATPL). The bulk of the flying training for this license is conducted in state-of-the-art fixed wing simulators, the intent being to reduce the cost for both the airline and the prospective license holder. In addition, so-called "zero flight time training (ZFTT)" [3] means that a pilot can gain a Type Rating on an aircraft using a training syllabus on a suitably qualified flight simulator. ZFTT may be conducted only in a flight simulator qualified in accordance with JAR-STD Level C or D simulators [3,65] and user approved for ZFTT by the Authority.

For research purposes, flight simulators can be used both, at a basic level and at an aircraft programme level. Figs. 3 and 4 show examples of research simulators used for research into flight control systems, handling qualities and cockpit interfaces [5]. Fig. 3 shows the research simulators used in the European project ARISTOTEL - Aircraft and Rotorcraft Pilot Couplings–Tools and Techniques for Alleviation and Detection- (2010–2013) [14–33]. The results from this project form the bulk of the remainder of this

¹ The full flight simulators (FFS) can be divided in four levels of fidelity: (1) Level A - A motion system is required with at least three degrees of freedom. Airplanes only; (2) Level B - Requires three axis motion and a higher-fidelity aerodynamic model than does Level A. The lowest level of helicopter flight simulator. (3) Level C - Requires a motion platform with all six degrees of freedom. Also lower transport delay (latency) over levels A & B. The visual system must have an outside-world horizontal field of view of at least 75 degrees for each pilot. (4) Level D - The highest level of FFS qualification currently available. Requirements are for Level C with additions. The motion platform must have all six degrees of freedom, and the visual system must have an outside-world horizontal field of view of at least 150 degrees, with a Collimated (distant focus) display. Realistic sounds in the cockpit are required, as well as a number of special motion and visual effects.

Download English Version:

<https://daneshyari.com/en/article/1719206>

Download Persian Version:

<https://daneshyari.com/article/1719206>

[Daneshyari.com](https://daneshyari.com)