**PROJECT**

**ARISTOTEL**

**AIRCRAFT and ROTORCRAFT PILOT COUPLINGS TOOLS AND TECHNIQUES FOR ALLEVIATION and DETECTION**

**Funding:** European (7th RTD Framework Programme)

**Duration:** Oct 2010 - Sep 2013

**Status:** Complete with results

**Total project cost:** €3,843,228

**EU contribution:** €3,003,652

**Call for proposal:** FP7-AAT-2010-RTD-1

**CORDIS RCN:** 96102

**Background & policy context:**

The ARISTOTEL project was challenged with ensuring aircraft safety and aimed to reduce the aircraft and rotorcraft accidents caused by a particularly unfavourable category of phenomena: aircraft-pilot-couplings and rotorcraft-pilot-couplings (A/RPCs).

Generally, A/RPCs are defined as inadvertent, sustained aircraft oscillations which are a consequence of an abnormal joint enterprise between the aircraft and the pilot. Experiences at the start of this project showed that modern designs were being increasingly confronted with dangerous A/RPCs. The reason for this was that modern aircraft feature a significant level of automation in their flight-control-systems (FCS). The FCS are generally intended to relieve pilot workloads and allow operations in degraded weather and visibility conditions. Especially in the modern rotorcraft, there seemed to be embedded tendencies predisposing the FCS system towards dangerous RPCs. As the level of automation was likely to increase in future designs, extending to smaller aircraft and to different kinds of operations, the consequences of the pilot fighting the FCS system and inducing A/RPCs needed to be eradicated.

**Objectives:**

It was the goal of this project to develop the design tools and techniques needed to detect and alleviate the A/RPC problems.

**Methodology:**

The end products of the project were to be:

- Advanced vehicle-pilot-FCS simulation models for rigid body and aero servo elastic A/RPC analysis;
- A/RPC design guidelines and criteria;
- protocols and guidelines for A/RPC flight simulator training.

All results were to be directly usable by the aerospace industry in the design process for improving flight safety. The project would contribute in this sense to:

- the minimization of the factors that lead to pilot loss of control resulting in increased enhancement of the European aircraft safety and;
- would strengthen the European Aeronautics Industry competitiveness in their time- and cost-effective design tools.

**Parent Programmes:**

**FP7-TRANSPORT - Transport (Including Aeronautics) - Horizontal activities for implementation of the transport programme (TPT)**

**Institute type:** Public institution
**Institute name:** The European Commission  
**Funding type:** Public (EU)

## Lead Organisation:

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<thead>
<tr>
<th>Organisation</th>
<th>Address</th>
<th>EU Contribution</th>
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<tbody>
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<td>Technische Universiteit Delft</td>
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## Partner Organisations:

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EU Contribution: €233,750

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Organisation Website:
http://www.liv.ac.uk

EU Contribution: €440,488

Technologies:

- Aircraft operations and safety
- Aircraft-pilot-couplings and rotorcraft-pilot-couplings (A/RPCs)

Development phase: Research/Invention

Key Results:

The incidence of A/RPC events could be reduced through more effective and consistent use of tools and capabilities during modelling, analysis, design and testing. We tried in this project to understand
"exotic" couplings that were responsible for A/RPCs. We understood more from the complexity of the pilot and how this related to vehicle dynamics. We acquired more knowledge on how to test for A/RPC. With this we proposed new approaches to address the A/RPC risk. At the time of the project it was to be a future task to integrate these findings into the design-team efforts to address A/RPC.

**Innovation aspects**

- **Rigid body RPC**

It was found that, once the RPC has been triggered, all pilots tried to adapt their strategy to the new dynamics of the aircraft by using a combination of low-frequency lag and high-frequency lead equalisation to compensate for the reduced phase margin they had due to the added time delay. The University of Liverpool proposed a new real-time detection tool for A/RPC, the so-called Phase Aggression Criterion (PAC). PAC achieved a 'detection' of an A/RPC through the observation of the PVS phase distortion and the pilot input rate.

Observing pilot input allowed one to check that the pilot was coupled with the oscillations (a prerequisite for PIO) whilst the phase difference allowed one to see whether the commanded input was in-phase with the vehicle response. The combination of the two parameters at a finite point in time allowed the team to objectively assess whether an A/RPC had materialised. ONERA verified the applicability of fixed wing PIO prediction tools (such as bandwidth-phase delay and OLOP) to rotorcraft. By increasing the time delay in the pilot input, the result was a degradation in handling qualities, a decrease in aircraft bandwidth and an increase in the phase delay. From the different ADS-33 tasks flown in the simulator, it was shown that the precision hover (see Figure 1a) and the roll step (see Figure 1b) were suitable for exposing RPC tendencies while the slalom manoeuvre proved to be unsuitable for exposing RPC tendencies. The University of Liverpool related the so-called "Boundary Avoidance Tracking Concept" (BAT) and the "Optical Tau" theory to RPC events. BAT assumed that during an A/RPC event, the pilot behaviour was more like tracking and avoiding a succession of opposing events which could be described as boundaries. Tau theory was based on the premise that purposeful actions were accomplished by coupling the motion under control with either externally or internally perceived motion variables. Results showed that when pilots fly a roll-step manoeuvre there was a close correlation between the optical-tau and BAT.

- **Aeroelastic A/RPC Findings**

Comprehensive helicopter simulation models obtained by coupling flexible fuselage dynamics, main rotor and aeroelasticity, control chain dynamics and pilot behavioural dynamics were applied for RPC analysis of the IAR330 Puma and Bolkow Bo-105 helicopters. Results have shown that the passive coupling of the pilot biomechanics with the IAR330 Puma helicopter result

**Strategy targets**

Innovating for the future: technology and behaviour:

- A European Transport Research and Innovation Policy

Documents:
- Potential Triggers for A-RPC (Other project deliverable)
- Final Report Summary - ARISTOTEL (AIRCRAFT and ROTORCRAFT PILOT COUPLINGS – TOOLS AND TECHNIQUES FOR ALLEVIATION and DETECTION)

STRIA Roadmaps: Vehicle design and manufacturing

Transport mode: Air transport

Transport sectors: Passenger transport, Freight transport

Transport policies: Societal/Economic issues, Safety/Security,

Geo-spatial type: Other