NITROS
ENGINEERING FOR ROTORCRAFT SAFETY

# A Network for Innovative Training on Rotorcraft Safety (NITROS) and its Potential to Mitigate Rotorcraft Accidents

***A Recent Marie Skłodowska-Curie Activity in Europe for Joint Doctorates on Rotorcraft Safety***


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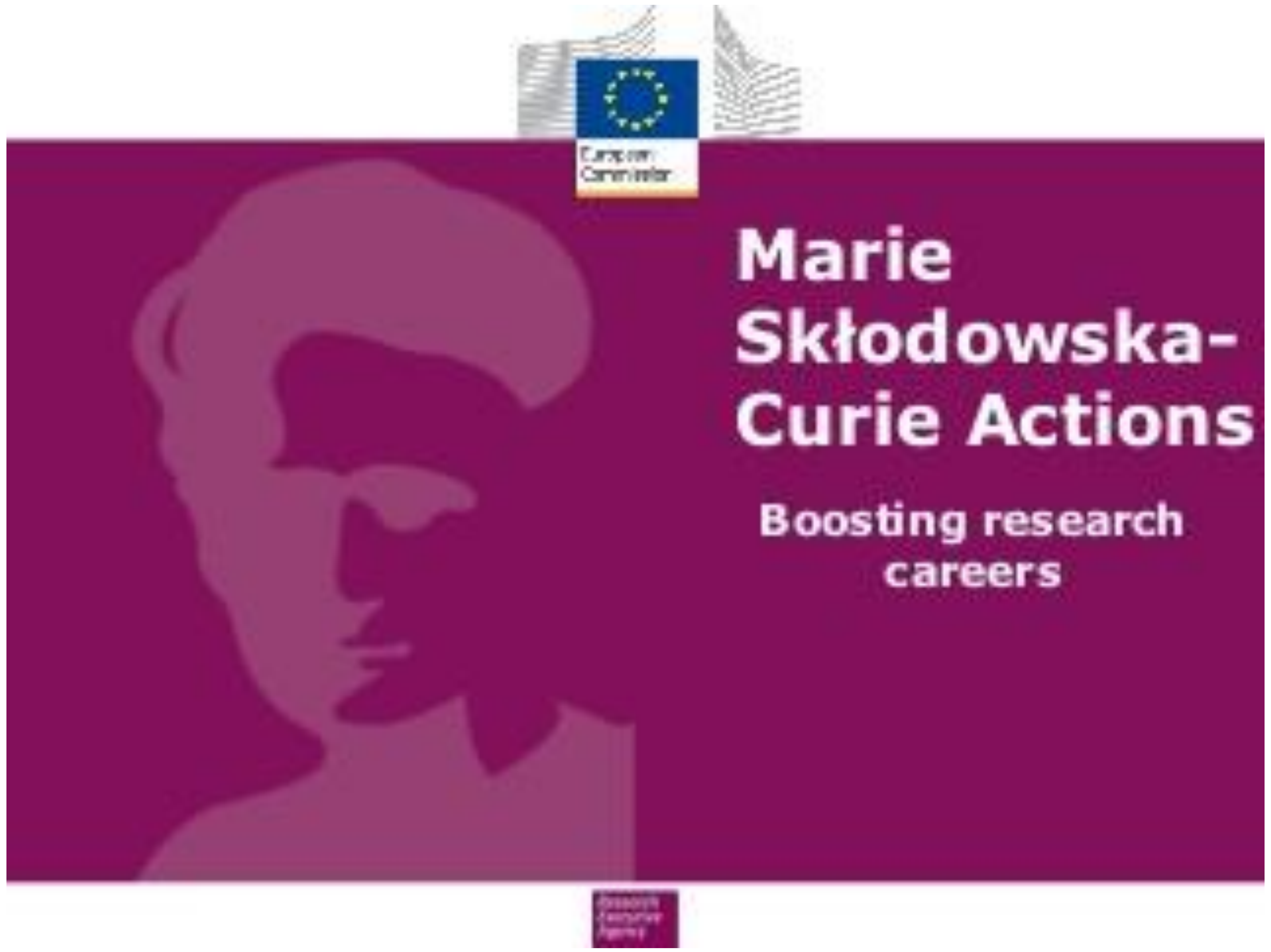
# OUTLINE

- Introduction to NITROS and Marie Sklodowska Curie Action
- Main scientific objective
- Main research goals
- Partnership
- Research Projects
- Conclusions

# INTRODUCTION

The goal of NITROS is to train a new generation of talented young aerospace engineers capable of developing innovative approaches in a unique cross-disciplinary research and training program encompassing Control Engineering, Computational Fluid Dynamics (CFD), Modelling and Simulation, Structural Dynamics and Human perception cognition and action, to address complex solutions for rotorcraft safety.

# WHAT IS NITROS




Strengthening skills, training and career development of early-stage researchers.

Initial Training Networks (ITN) offer early-stage researchers the opportunity to **improve their research skills, join established research teams** and **enhance their career prospects.**

In addition to generous research funding, scientists have the possibility to **gain experience abroad** and **in the private sector,** and to complete their training with **competences or disciplines useful for their careers.**

# MAIN SCIENTIFIC OBJECTIVE

Vision: FlightPath 2050 Goals

**“90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours”.**

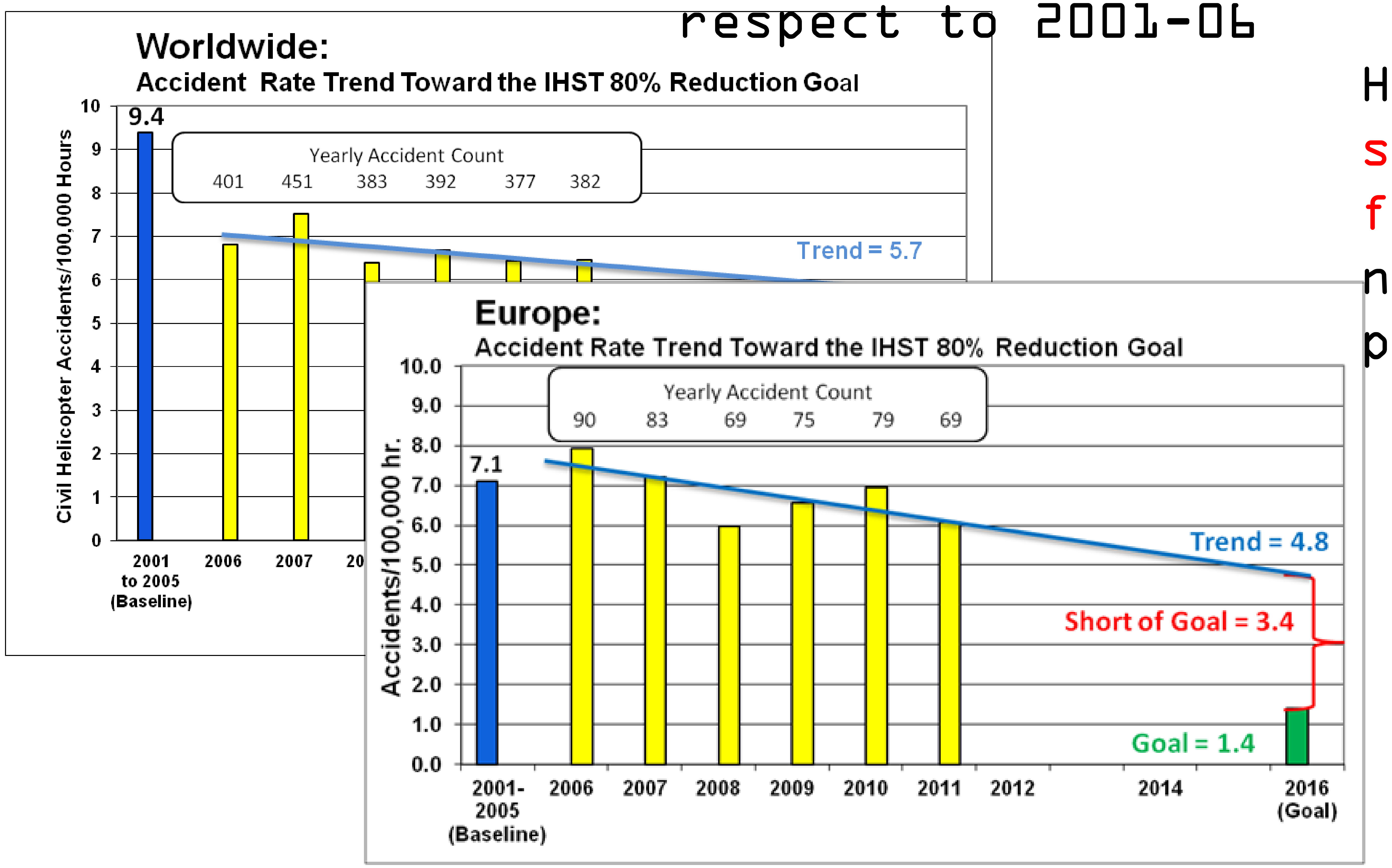
**This require that future vertical lift vehicles** give all-weather, 24/7 capacity to rotorcraft and aircraft capable of door-to-door operation with limited infrastructures.

“Rotorcraft play a significant role in public services, including search and rescue, and also in (regional) transport”.

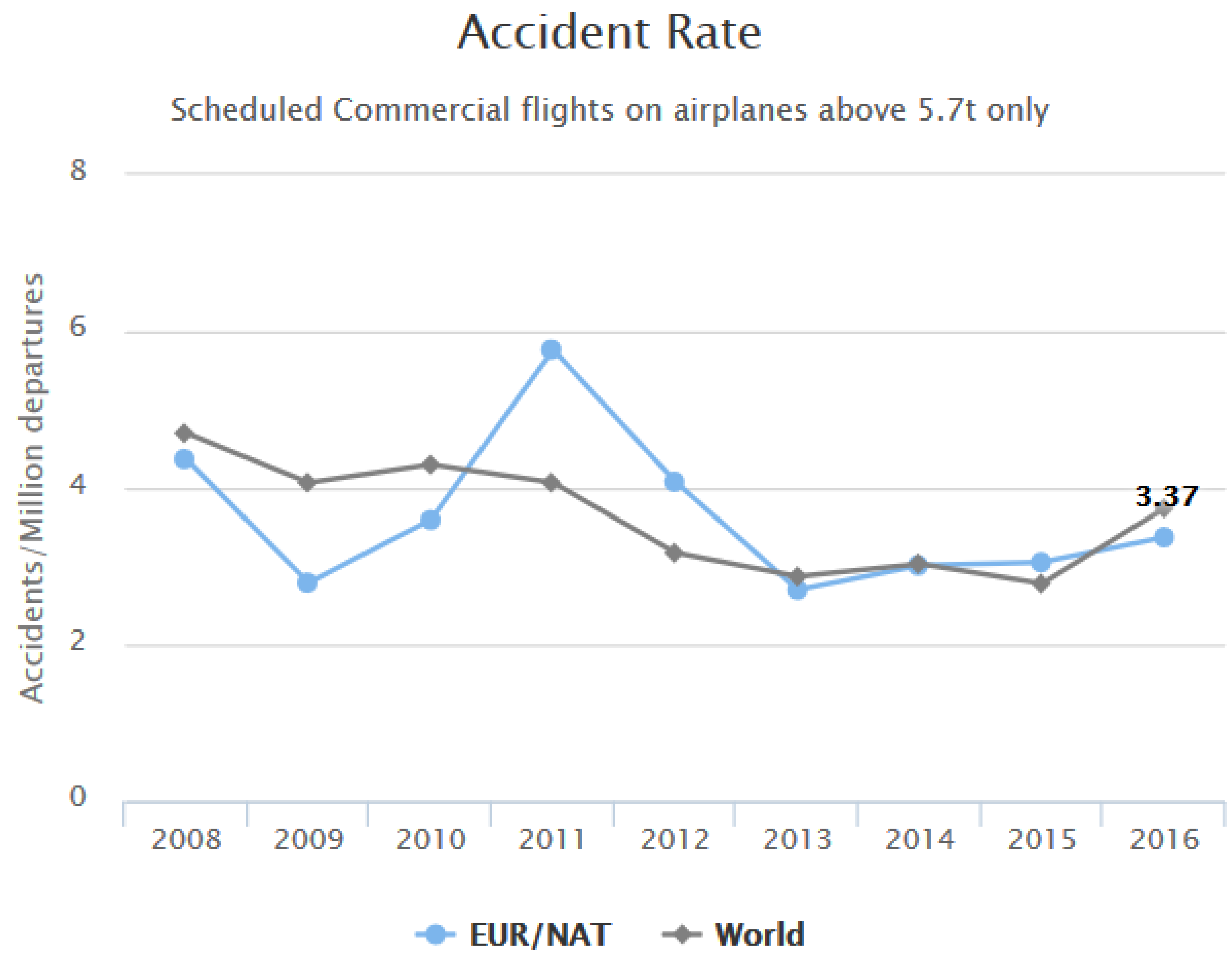
# MAIN SCIENTIFIC OBJECTIVE

Int. Helicopter Safety Team Goal: reduce the accident rate of 80% respect to 2001-06

Helicopter accident rate is still high, if compared to fixed wing aircraft, and it is not reducing at a sufficient pa



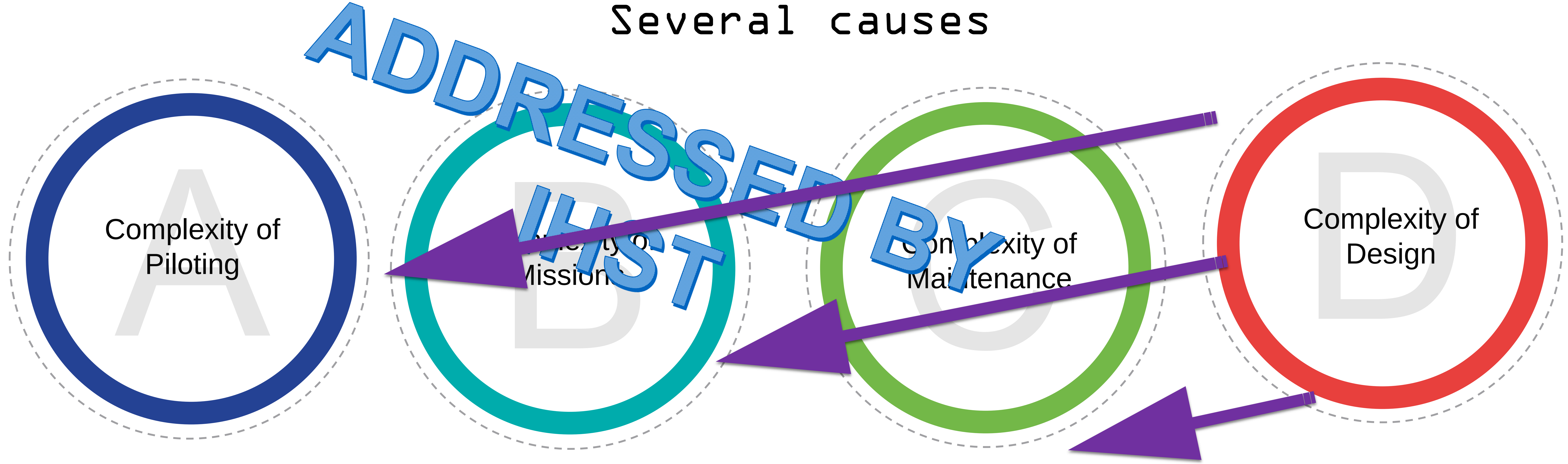

Source IHST [www.ihst.org](http://www.ihst.org)




Source ICAO. Avg flight time ~2h

# MAIN SCIENTIFIC OBJECTIVE

## Several causes




Complex, continuous, multiaxial, multi-task
"Rotary-wing pilots have to manage engines, rotors and their own mental reserves."
High Workload

Operation close to obstacles terrain, wires, often in IMC windy turbulent conditions
High Workload

There are numerous different 'mission critical' components to a helicopter, and each of these might have different maintenance periods

Highly multidisciplinary
High level of interconnection and mutual influence among different subsystems

# GOALS OF NITROS

## #1 Train for multidisiplinarity

To train the next generation of European aeronautical scientists and engineers on this peculiar
type of aircraft that have great potential to improve the effectiveness of the European transport network, developing the entrepreneurial attitude in them that is essential to introduce disruptive technological Innovations

## #2 Train to design for safety

To train the next generation engineers to avoid overlooking the impact that their design choices may have on flight safety, fostering the investigation of safety issues on innovative vertical take-off configurations that may assume an important role in the future European transport network

## #3 Innovation for safety

To introduce innovations in rotorcraft design that will enhance the safety of helicopters, to obtain a significant reduction of the accident rate up to 20% especially for future rotorcraft designs and
operations that will exploit the innovation generated by NITROS research

## #4 Network of excellence

To create a network of excellence of European research establishments and industry organisations dedicated to rotorcraft safety

# RESEARCH OBJECTIVES

Three main threats have been identified related to rotorcraft safety which led to three NITROS specific research objectives

VEHICLE

PILOT

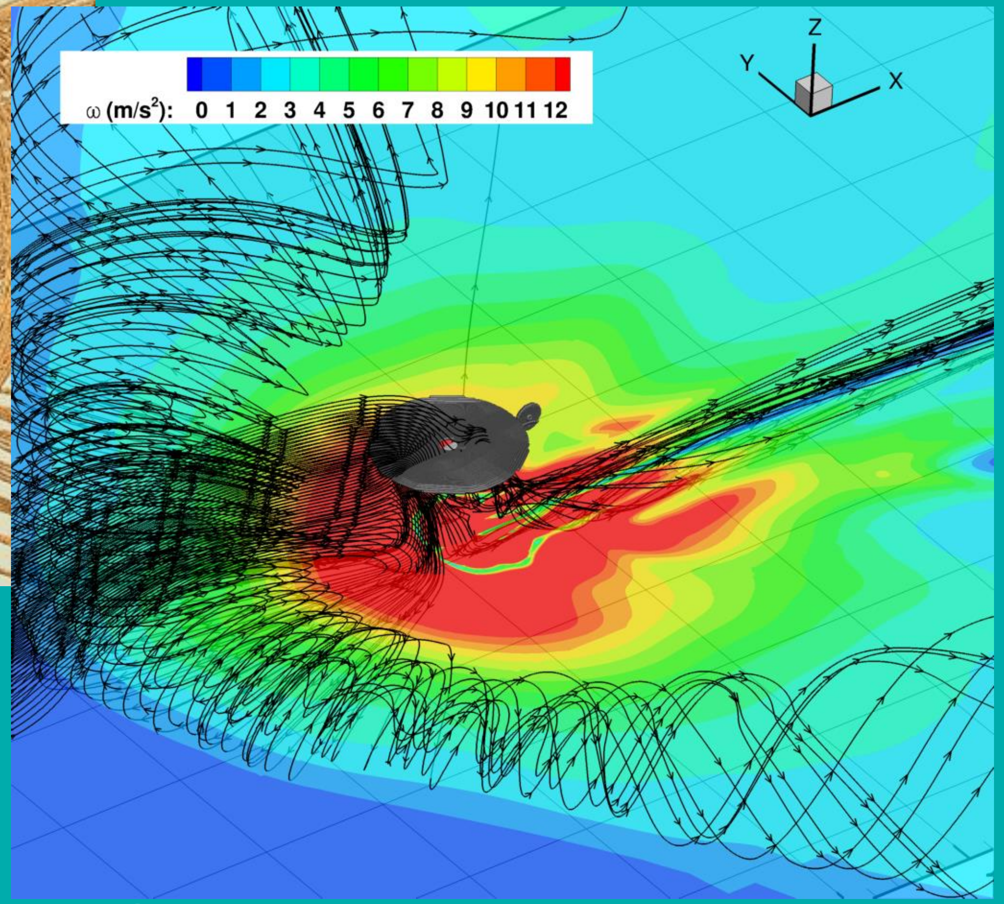
ENVIRONMENT

# RESEARCH OBJECTIVE #1

Develop a detailed framework for rotorcraft modelling integrating rigid-body and aero-servo-elastic modelling features capable of dealing with structural or propulsion/mechanical system failure in rotorcraft

# RESEARCH OBJECTIVE #2

Understand how humans can safely and efficiently use and be interfaced with rotorcraft technology.




# RESEARCH OBJECTIVE #3

Enhance the understanding of the unique and complex aerodynamic environment in which the rotorcraft are working, often in hostile conditions of wake encounter threats, un-desirable interactions with obstacles, icing and, brownout conditions

# THE PARTNERSHIP

POLITECNICO MILANO 1863

nlr

LEONARDO

Max-Planck-Institut für biologische Kybernetik

University of Glasgow

VIA VERITAS VITA

UNIVERSITY OF LIVERPOOL

FIAT LUX

Civil Aviation Authority

renewableUK

The voice of wind & marine energy

EUROCONTROL

TU Delft

Delft University of Technology

Bristow

# RESEARCH PROJECTS

SIMULATION AND PREVENTION OF ICE FORMATION AND SHEDDING ON ROTORCRAFT

IN SERVICE HEALTH MONITORING FOR ROTORCRAFT STRUCTURES

INNOVATIVE DESIGN FOR TILTROTOR COCKPIT FOR THE REDUCTION OF PILOT WORKLOAD

ROBUST FLIGHT CONTROL OF ROTORCRAFT MANOEUVRES IMMERSED IN OBSTACLE'S TURBULENCE

ROTORCRAFT WAKE MODELLING

DEVELOPMENT OF THE PHASE AGGRESSION CRITERION FOR ADVERSE ROTORCRAFT PILOT COUPLING PREDICTION AND REAL-TIME DETECTION (PAC)

MITIGATION OF AIRWAKE HAZARDS

MODELLING OF BROWN/WHITE-OUT

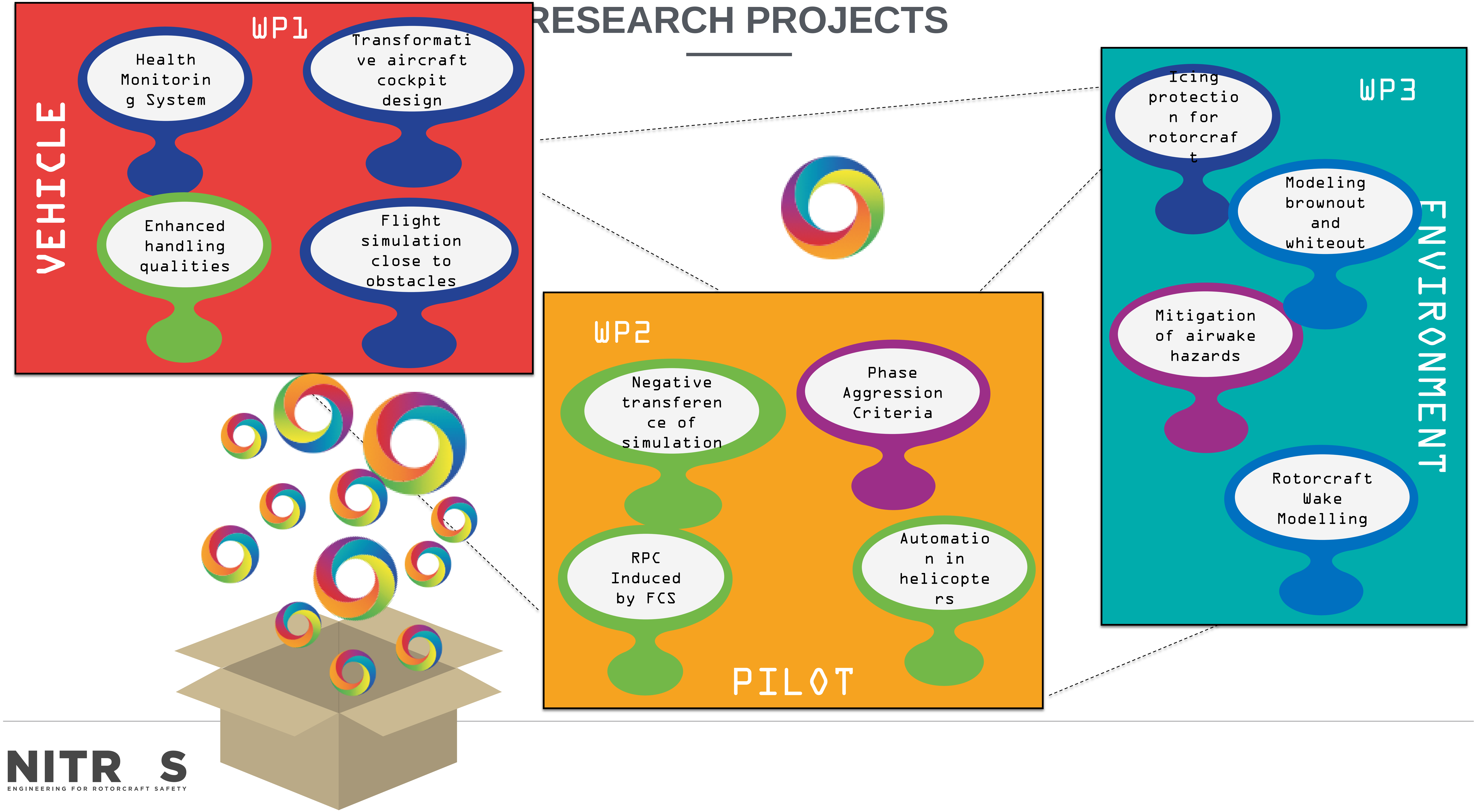
ENHANCED HELICOPTER HANDLING QUALITIES THROUGH VIBRATORY LOADS EXPLORATION

REVEALING ADVERSE ROTORCRAFT PILOT COUPLINGS INDUCED BY FLIGHT CONTROL SYSTEMS

UNDERSTANDING THE USE OF AUTOMATION IN HELICOPTERS

ALLEVIATING FLIGHT SIMULATOR NEGATIVE TRANSFERENCE FOR HELICOPTER OPERATIONS

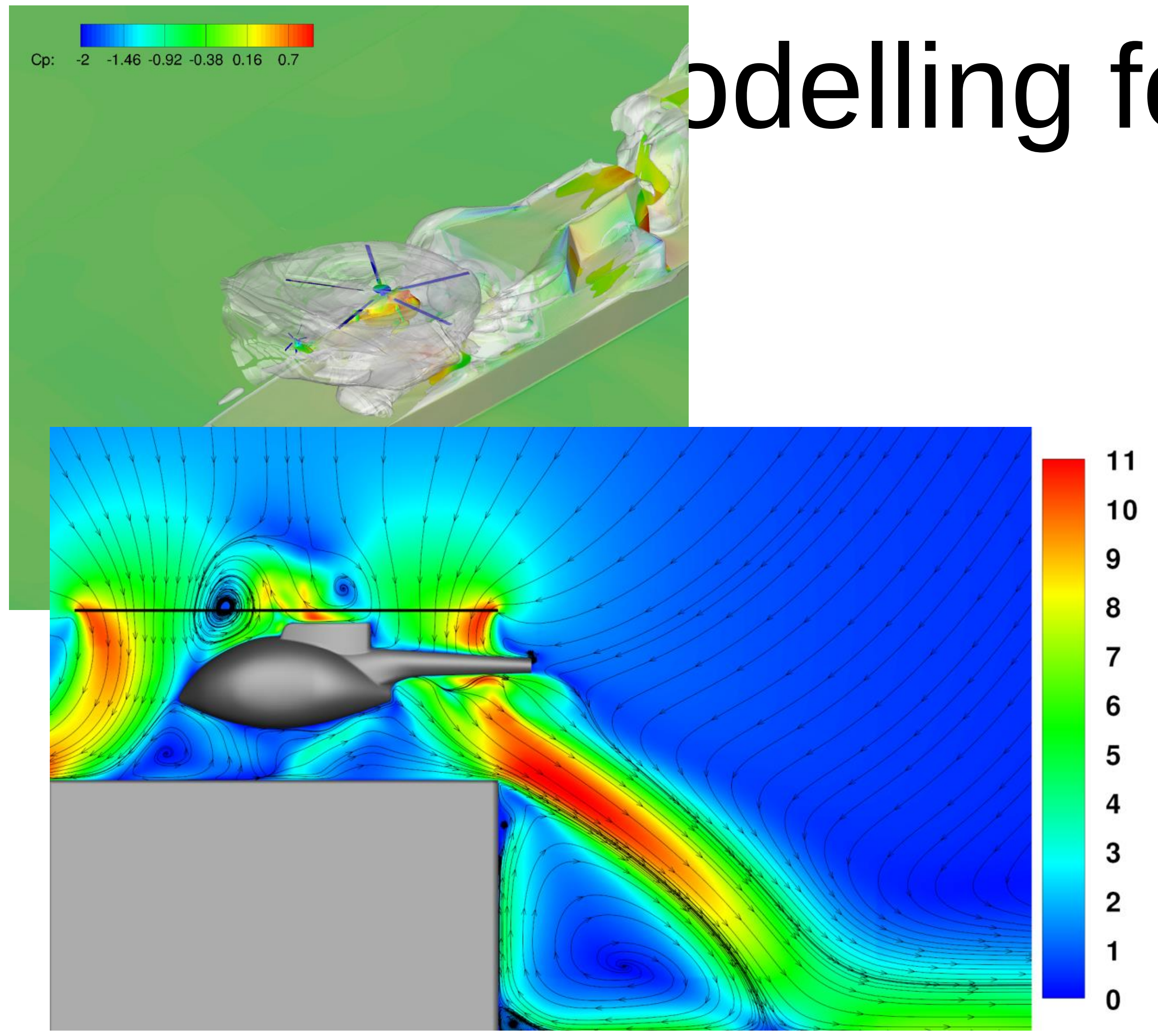
# RESEARCH PROJECTS



# INTERACTION WITH OBSTACLES AND WAKE MODELLING

#4 Flight mechanics of rotorcraft immersed in obstacle's turbulence

…odelling for rot… …n of airwake




Wind tunnel

CFD

Validation and definition of Reduced Order Models

Real time communication

Flight simulator

Real time communication

# DESIGN FOR SAFETY

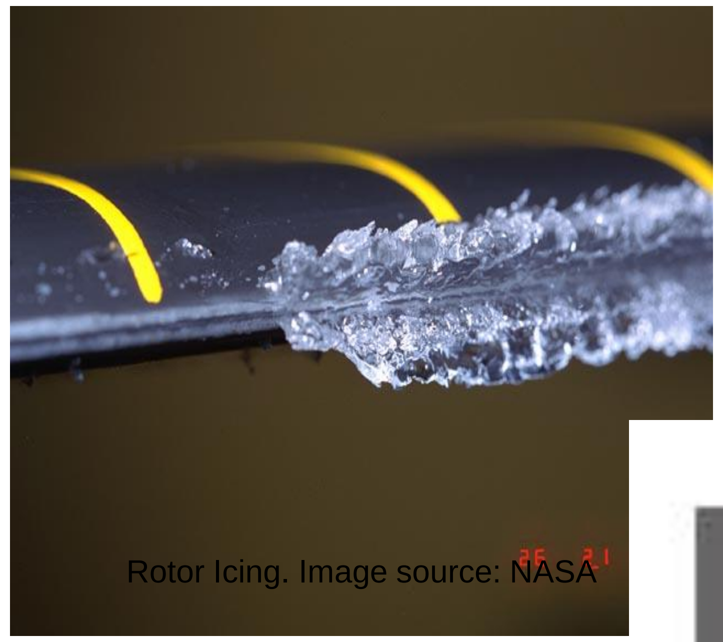
- Increase basic knowledge of flow fields close to obstacle
- Improve flight simulator training
- Help to design Robust Flight Control systems
- Increase the possibility to perform reduced cost qualification test
- Reduce the risk of qualification tests

# BROWNOUT and ICING

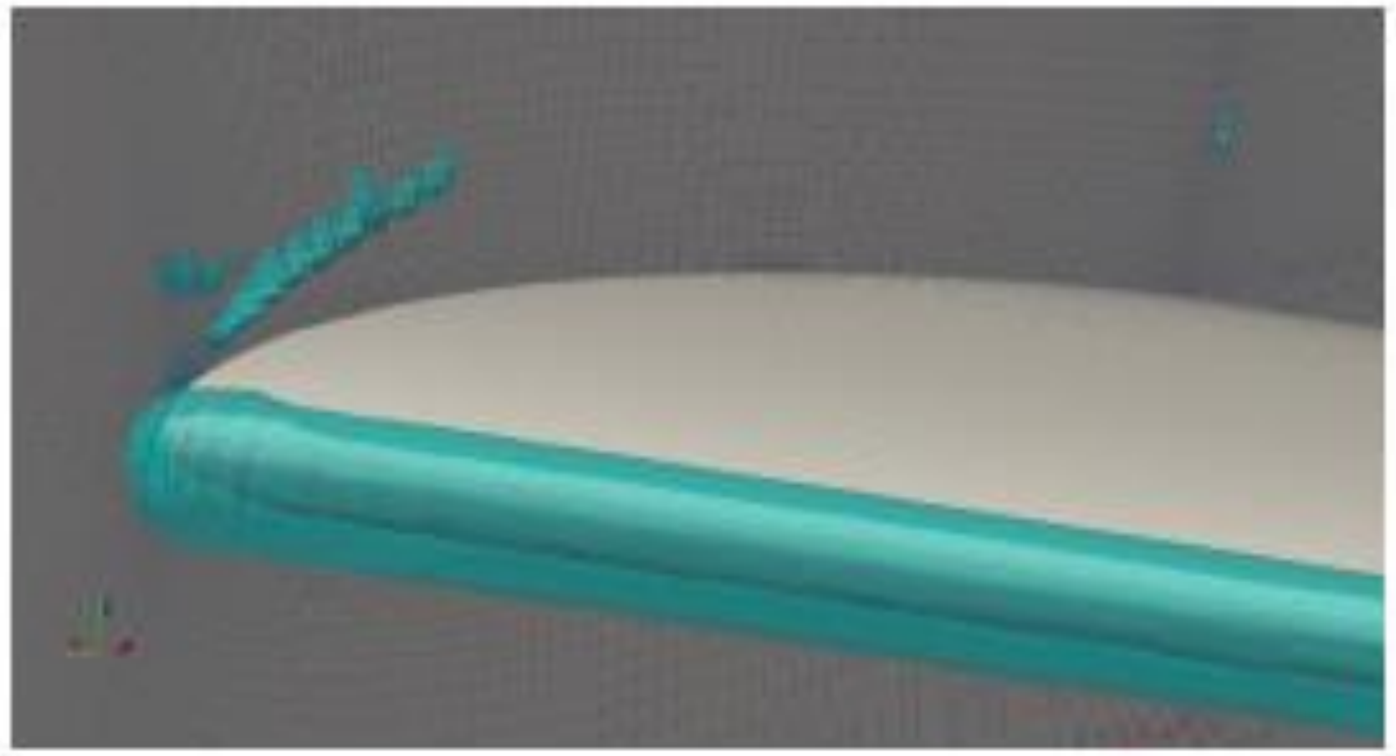
#4 Flight mechanics of rotorcraft immersed in obstacle's turbulence

#8 Wake modelling for rotary wings

CFD + Particle tracking



Rotor Icing. Image source: NASA

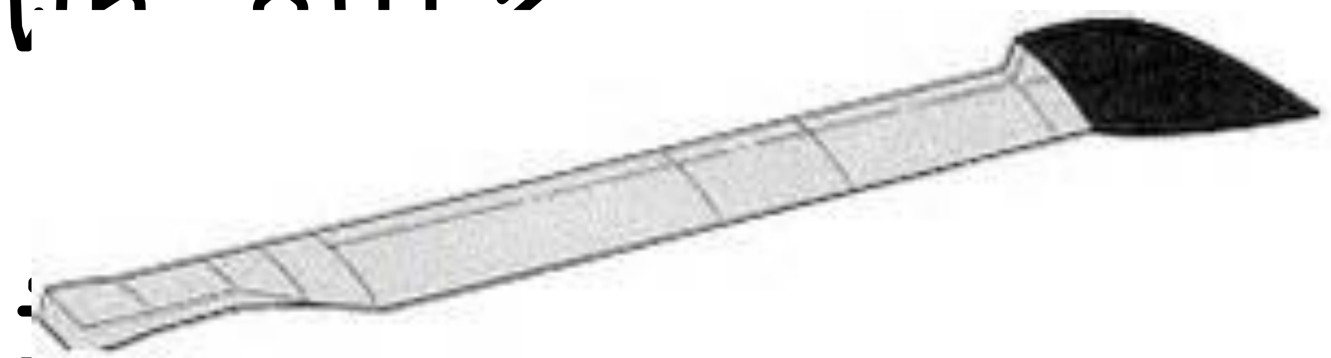


ICE Accretion and Shedding

Include those models into flight simulators to improve training

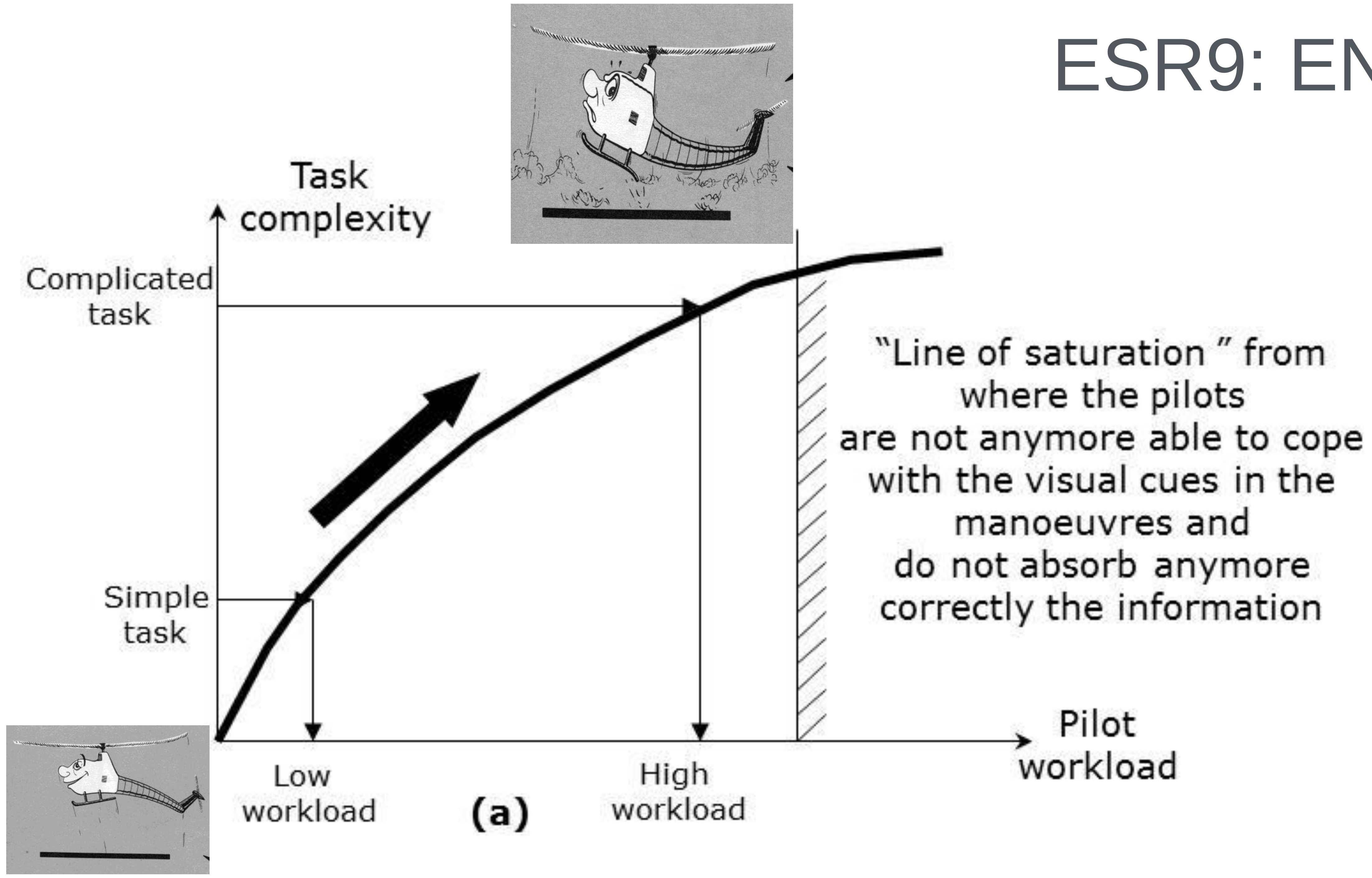
# DESIGN FOR SAFETY

- Could blade design reduce icing or brown out?



- Develop model for flight simulator training
- Help to design Robust Flight Control systems to deal with those conditions
- Increase the possibility to perform reduced cost virtual qualification test
- Reduce the risk of qualification tests

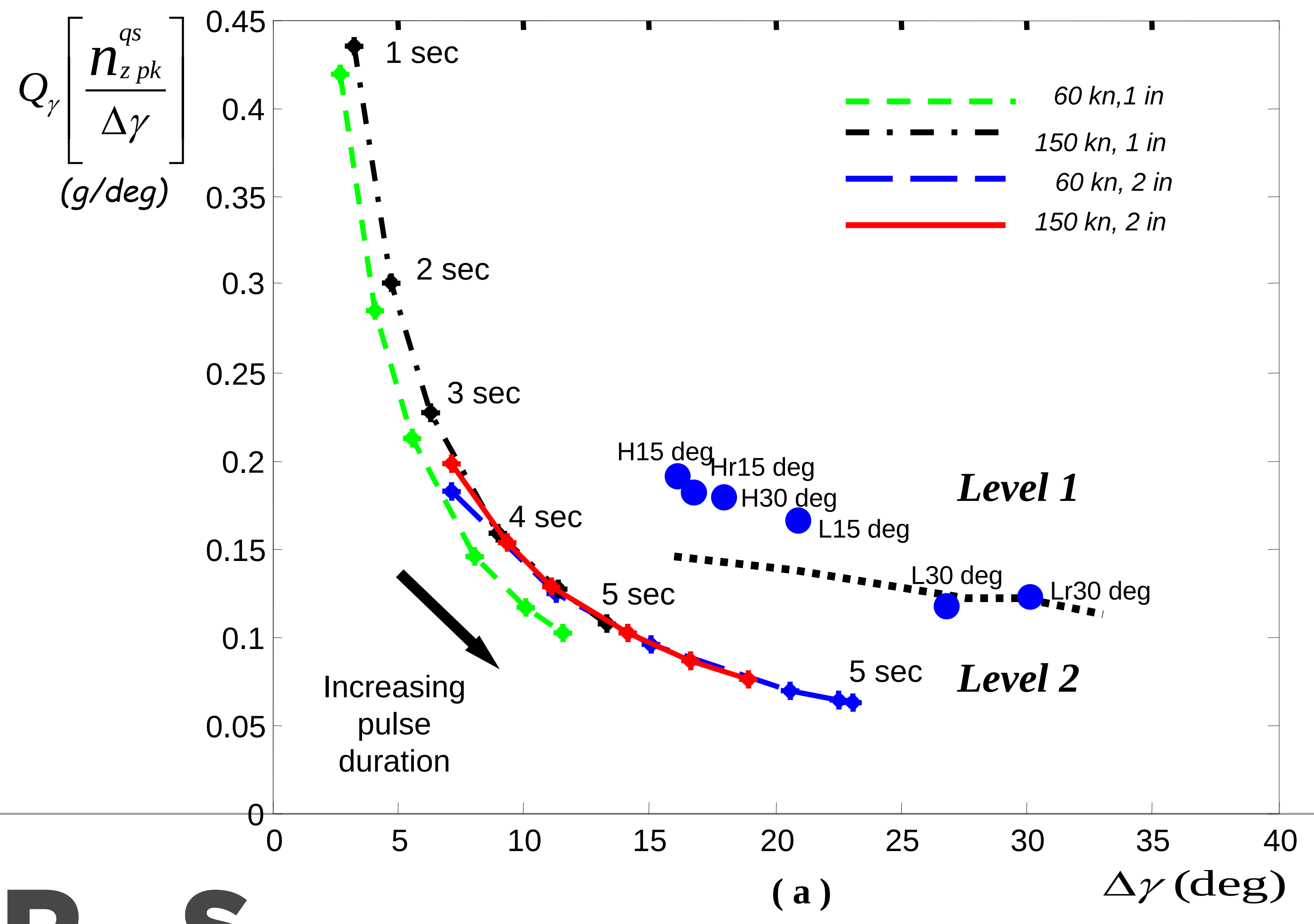
# ESR9: ENHANCED HELICOPTER HANDLING QUALITIES THROUGH VIBRATORY LOADS EXPLORATION




Pilot workload and handling qualities (HQs) are influenced by task complexity. With increasing task complexity, the vibration sources tend to dominate the discomfort of the helicopters' occupants.

Main question: What is the relation between handling qualities and helicopter vibratory activity as related to the pilot ability to fly different tasks/missions?

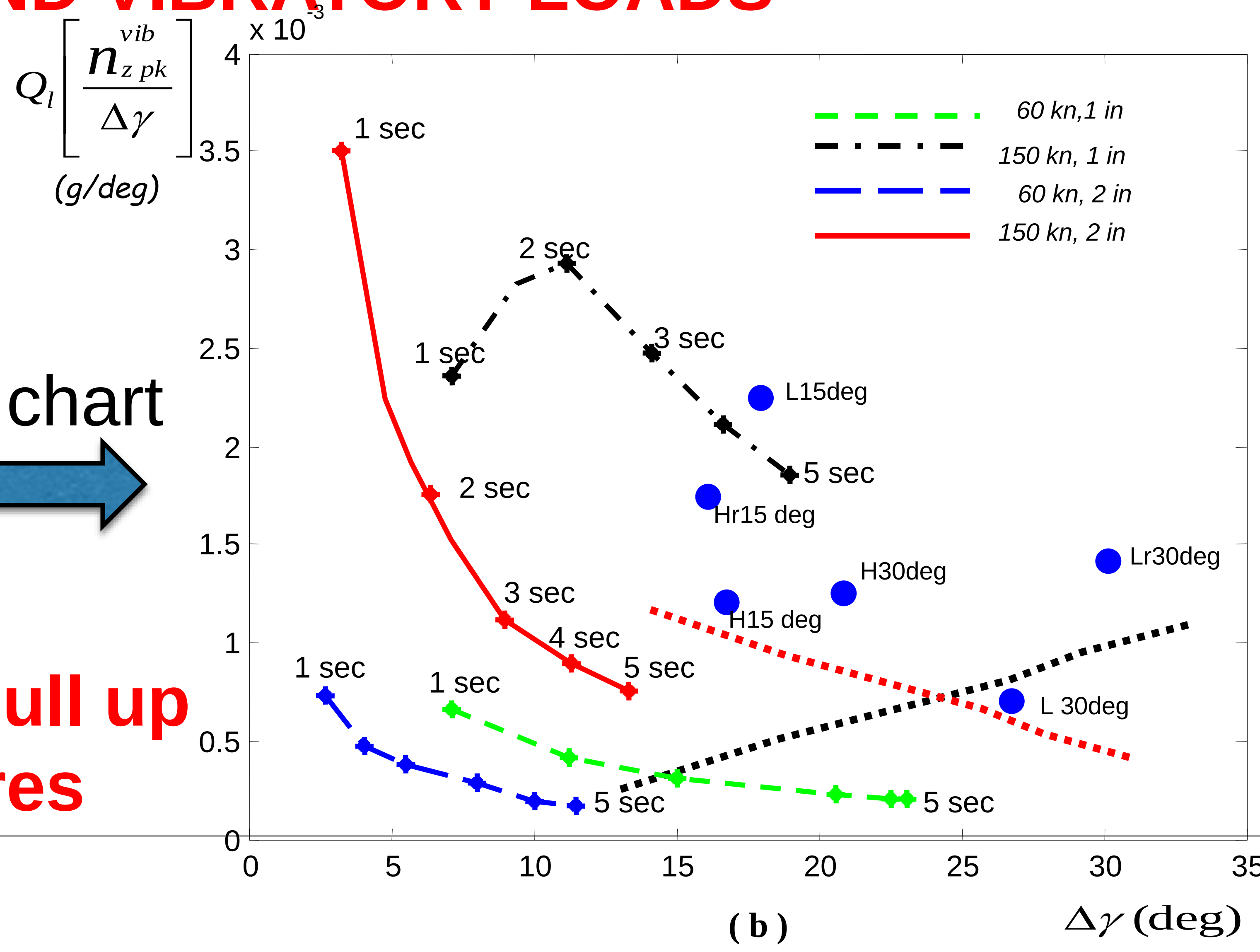
**GOAL PROJECT : DEVELOP MULTIDISCIPLINARY CRITERIA GIVING THE CORRELATION BETWEEN TASK PERFORMANCE AND VIBRATORY LOADS**




HQ chart

Vibratory chart

**Example of pull up manoeuvres**

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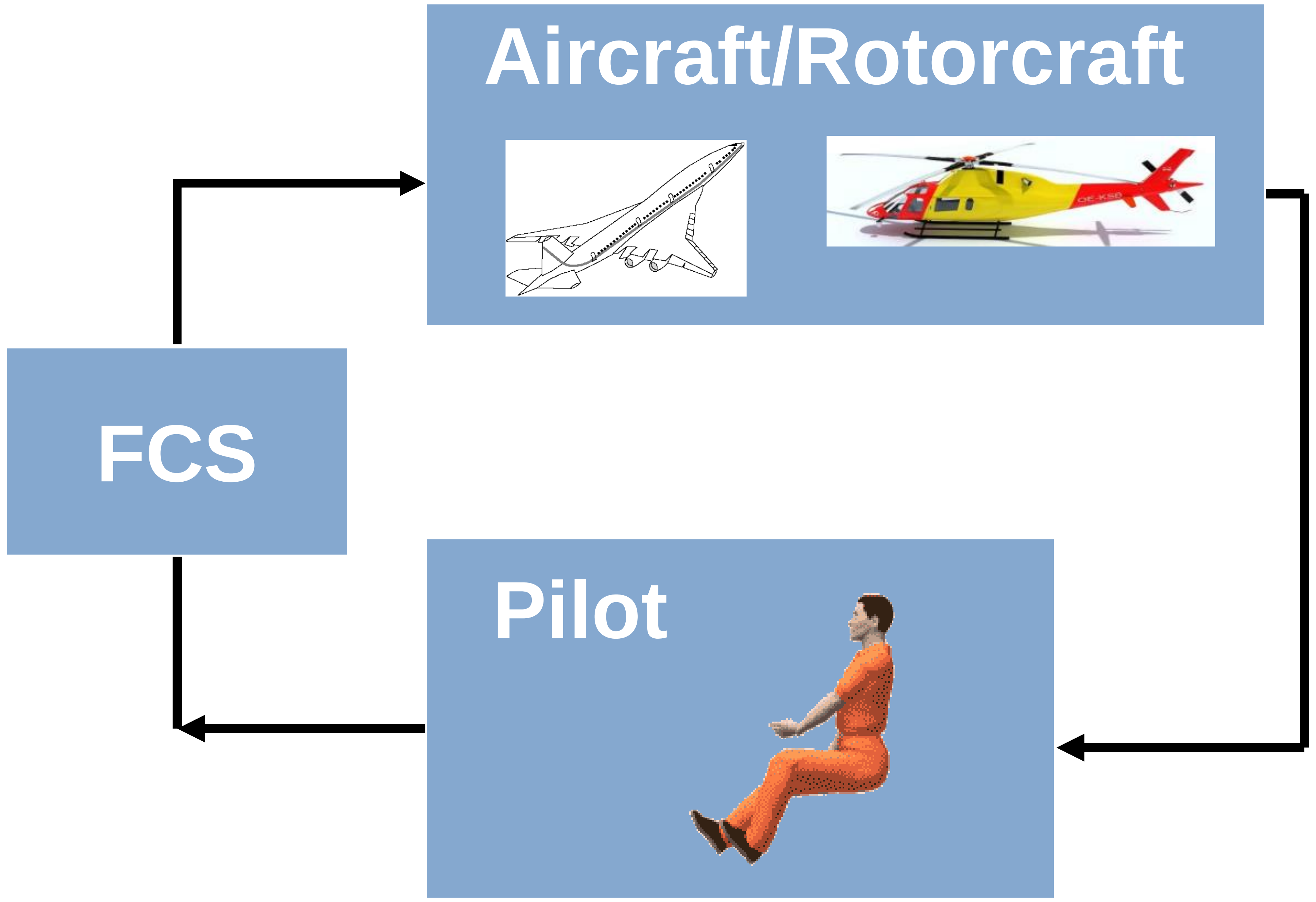
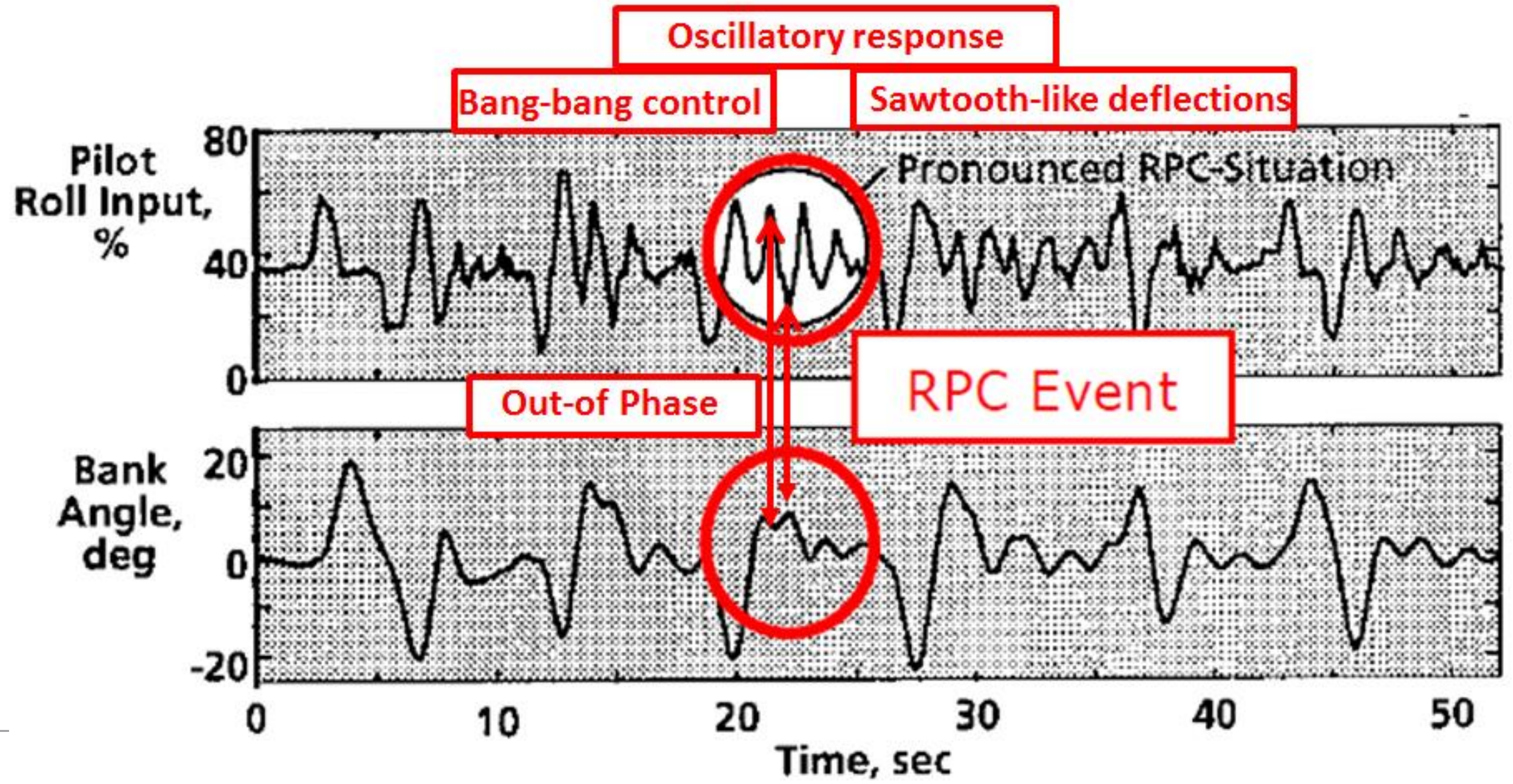



# ESR 10: Revealing adverse Rotorcraft Pilot Couplings (RPC) induced by Flight Control Systems

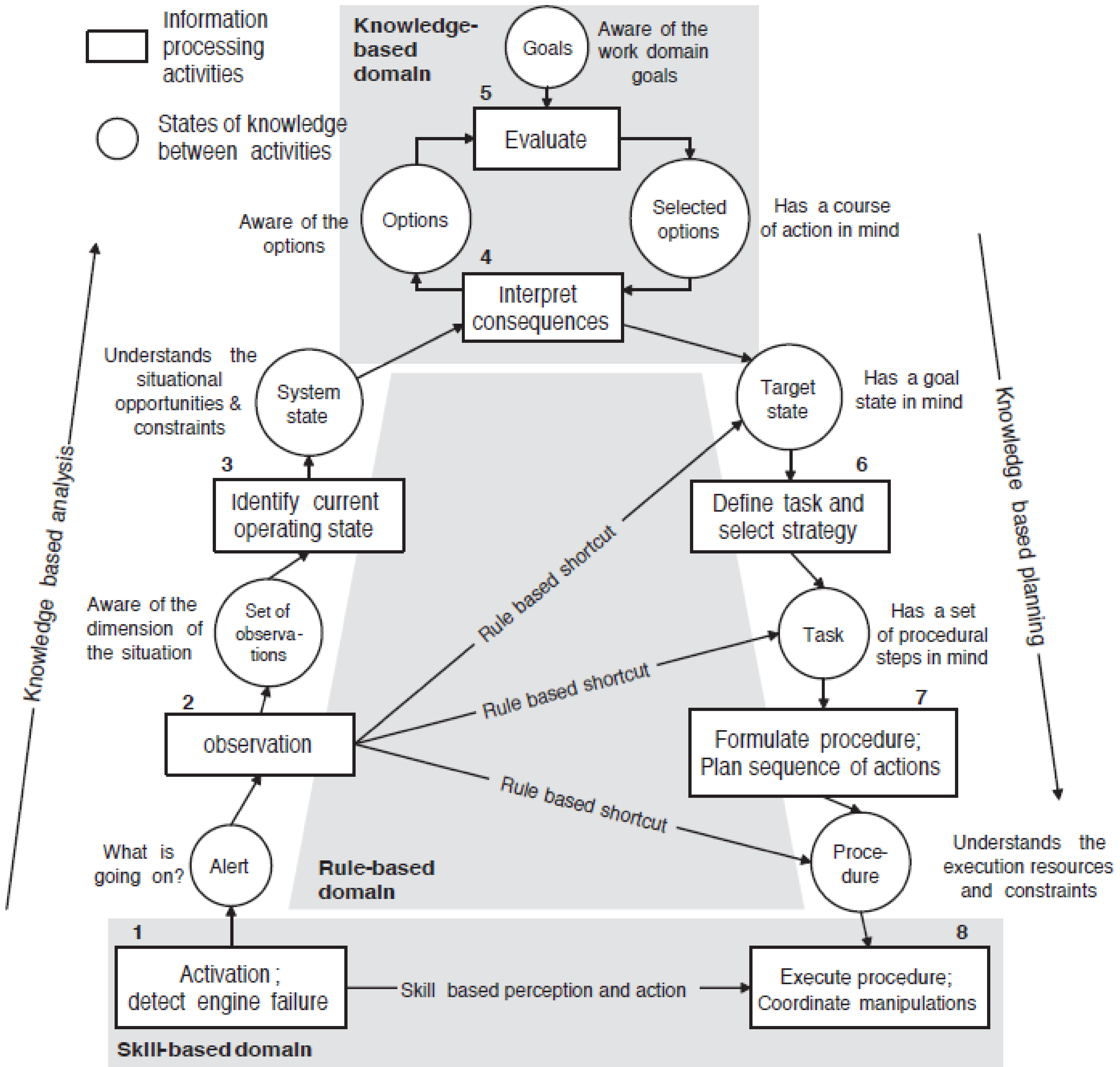
- Modern helicopter designs seem even more sensitive to rotorcraft-pilot couplings RPC (a la PIO/PAO). The problem seems to reside also into modern flight control systems

- Main question: What are the effects of modern FCS onto RPC problem? How can we prevent and alleviate such problems in future designs?




**GOAL PROJECT : PREDICT AND ALLEVIATE THOSE RPCs RELATED TO MALFUNCTIONING OF AUTOMATIC FLIGHT CONTROL SYSTEM THAT CAN RESULT IN LOSS OF VEHICLE**

# ESR11: UNDERSTANDING THE USE OF AUTOMATION IN HELICOPTERS




The Decision Ladder as a modeling tool for identifying skill-, rule- and knowledge-based behavior (Rasmussen, 1986)

Automatic equipment functions best when the workload is light and the task routine; when the task requires assistance or workload is high, the automatic equipment seems of least assistance.

Main question: How much automation does the pilot need? … especially in the case of vehicle loss of control associated with the automation sophistication

**GOAL PROJECT : DEVELOP GUIDELINES RELATED TO NEW 'IMPROVED' AUTOMATIC CONTROL SYSTEMS THAT BETTER SUPPORT PILOTS IN NORMAL AND EMERGENCY CASES.**



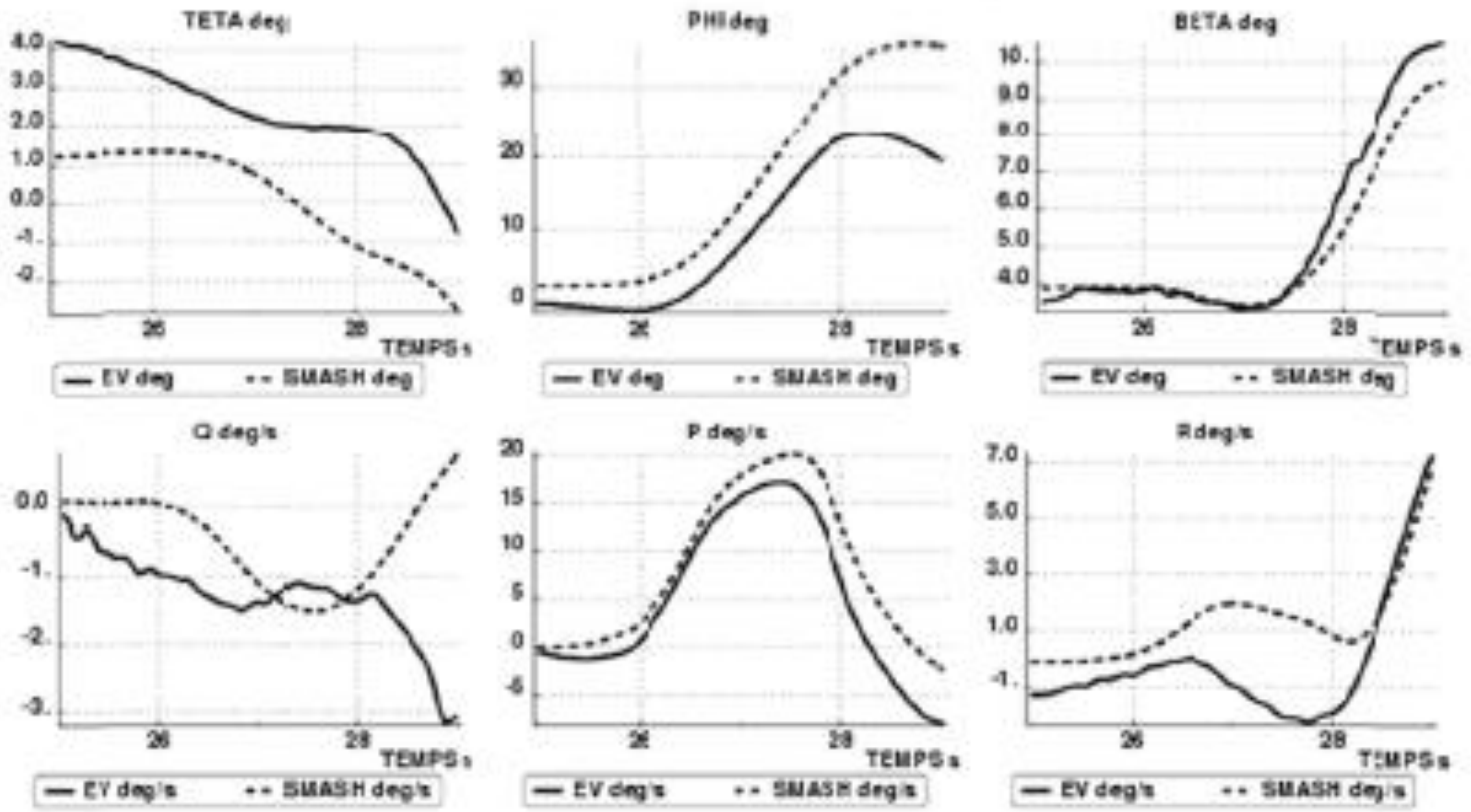
# ESR12: ALLEVIATING FLIGHT SIMULATOR NEGATIVE TRANSFER FOR HELICOPTERS

- Helicopter simulators can induce pilot "negative transference", incorrect pilot responses and understanding of helicopter's behavior.

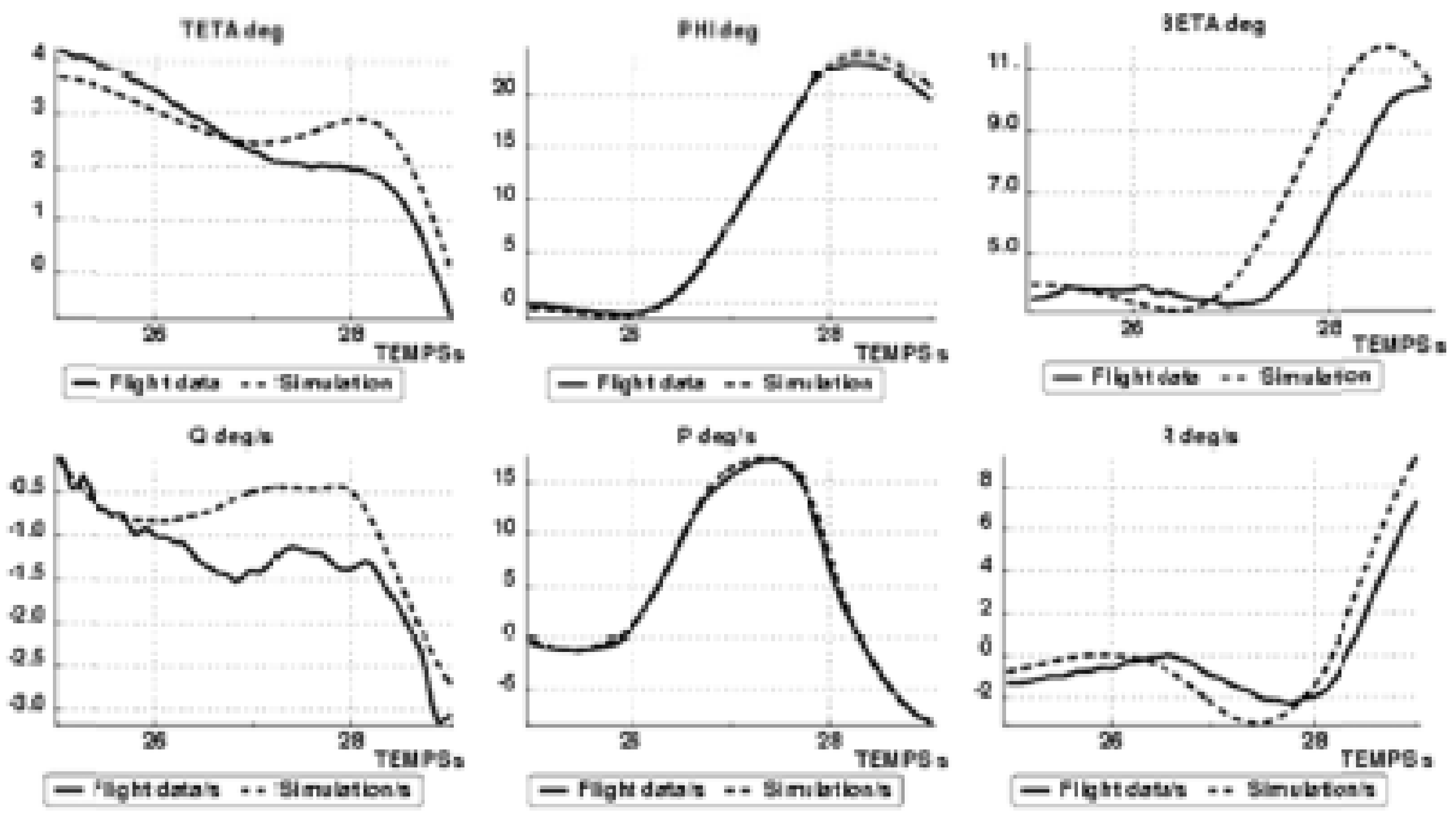
- Main question: What is the relation between pilot transfer of training in the simulator and the mathematical model of the simulator?

**GOAL PROJECT : DEVELOPING CRITERIA GIVING THE RELATION BETWEEN THE PILOT TRANSFER OF TRAINING IN THE SIMULATOR AND THE MATHEMATICAL MODEL OF THE SIMULATOR**

**Model before tuning**

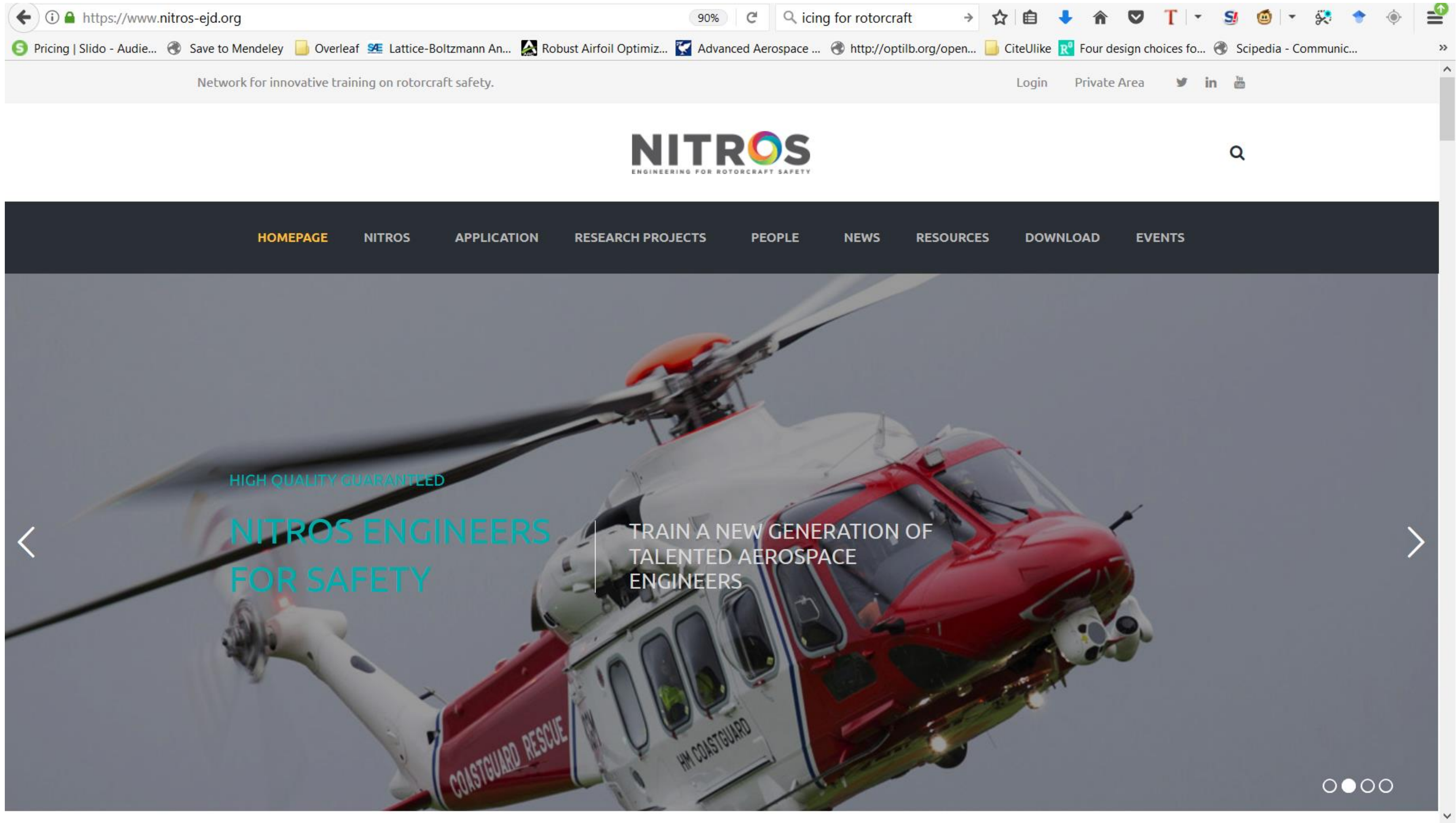



**Model after non-physical tuning**




Example of simulator model behaviour before and after tuning (Pavel, Padfield et. al., 2013)

# INFORMATION

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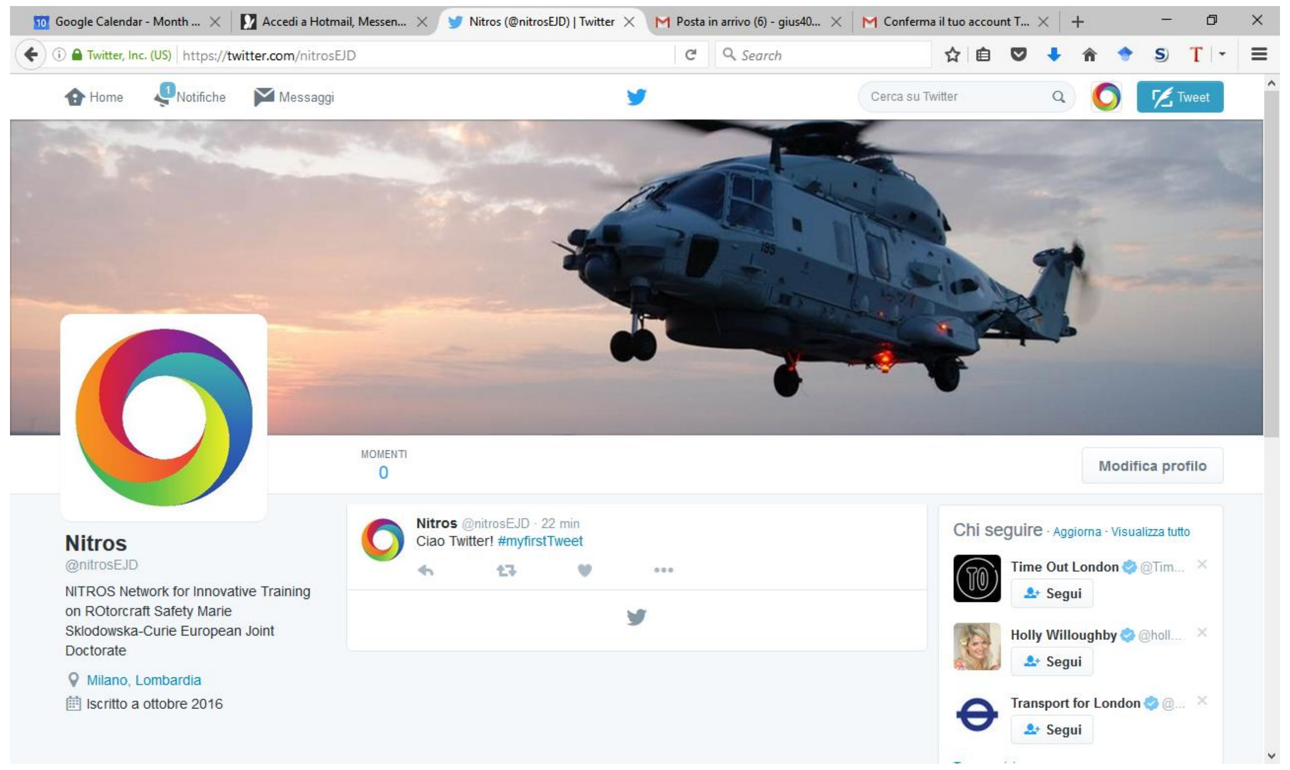

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