Development and Application of Advanced Control Design Techniques for Challenging Dynamic Processes

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Introduction

- Recent projects and research issues developed at the Engineering Department of the Ferrara University (ITALY)
- Topics and suggestions for cooperations and European Projects

Projects & Research Topics

- Modelling & Control Design of a Diesel Engine with *Pollution Constraints* (2007-2009)
- *Computerised Decision Support Systems* for Oral Anticoagulant Treatment (OAT) Dose Management (2005-2007)
- Development of *Fault Tolerant NGC (Navigation, Guidance & Control)* Algorithms for CUAV (Civil Unmanned Aerial Vehicle) Patrolling & Rescue Missions in Harsh Environment (2004-2008, 2009-2011)
- Just started (2009 - 2011):
  - Mobile robots & SLAM - Simultanous Localization And Mapping
  - Image based visual servoing of robot manipulators - application to robotic surgery

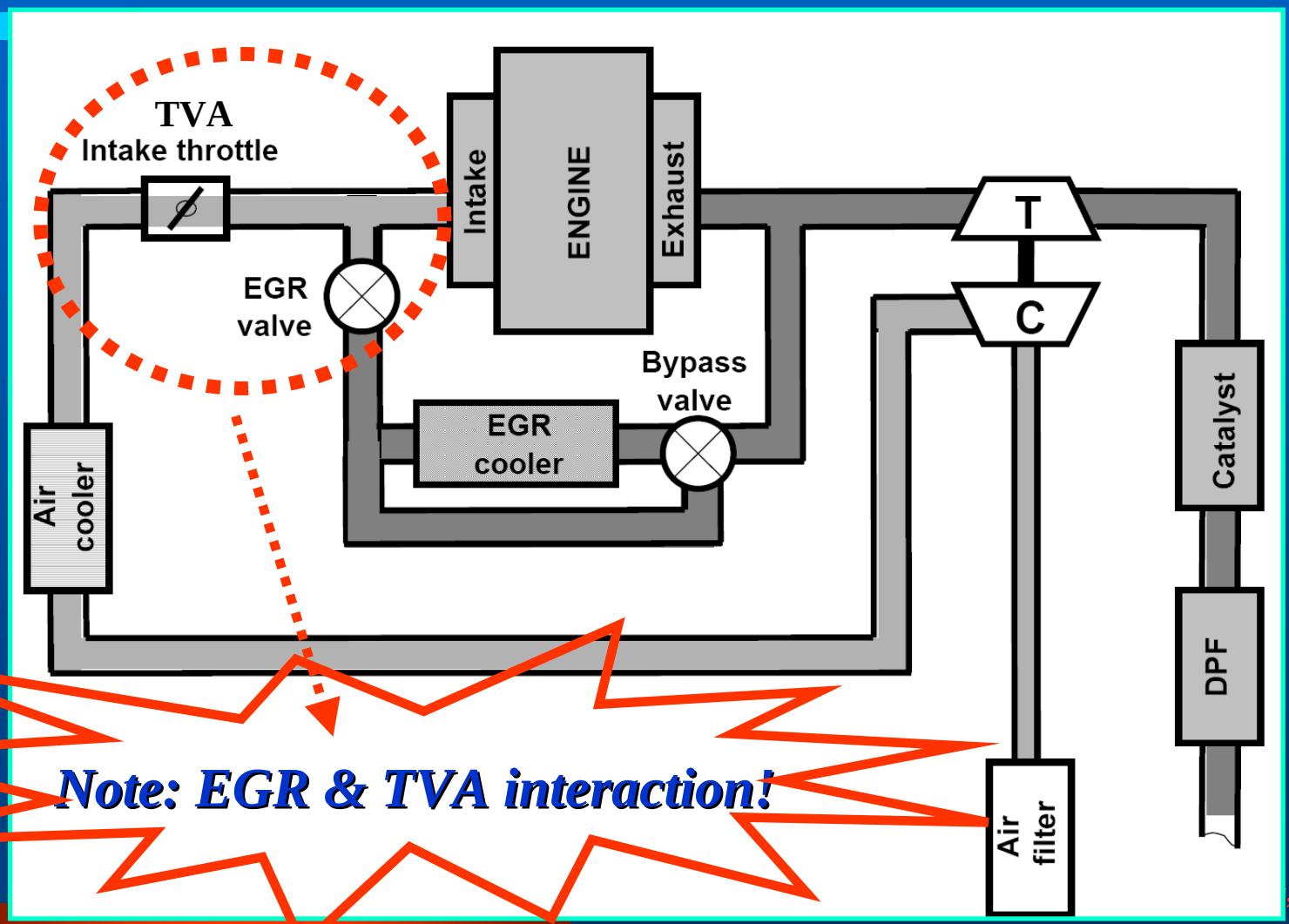
Modelling & Control Design of a Diesel Engine with Pollution Constraints

9th March, 2009. Duisburg, Germany

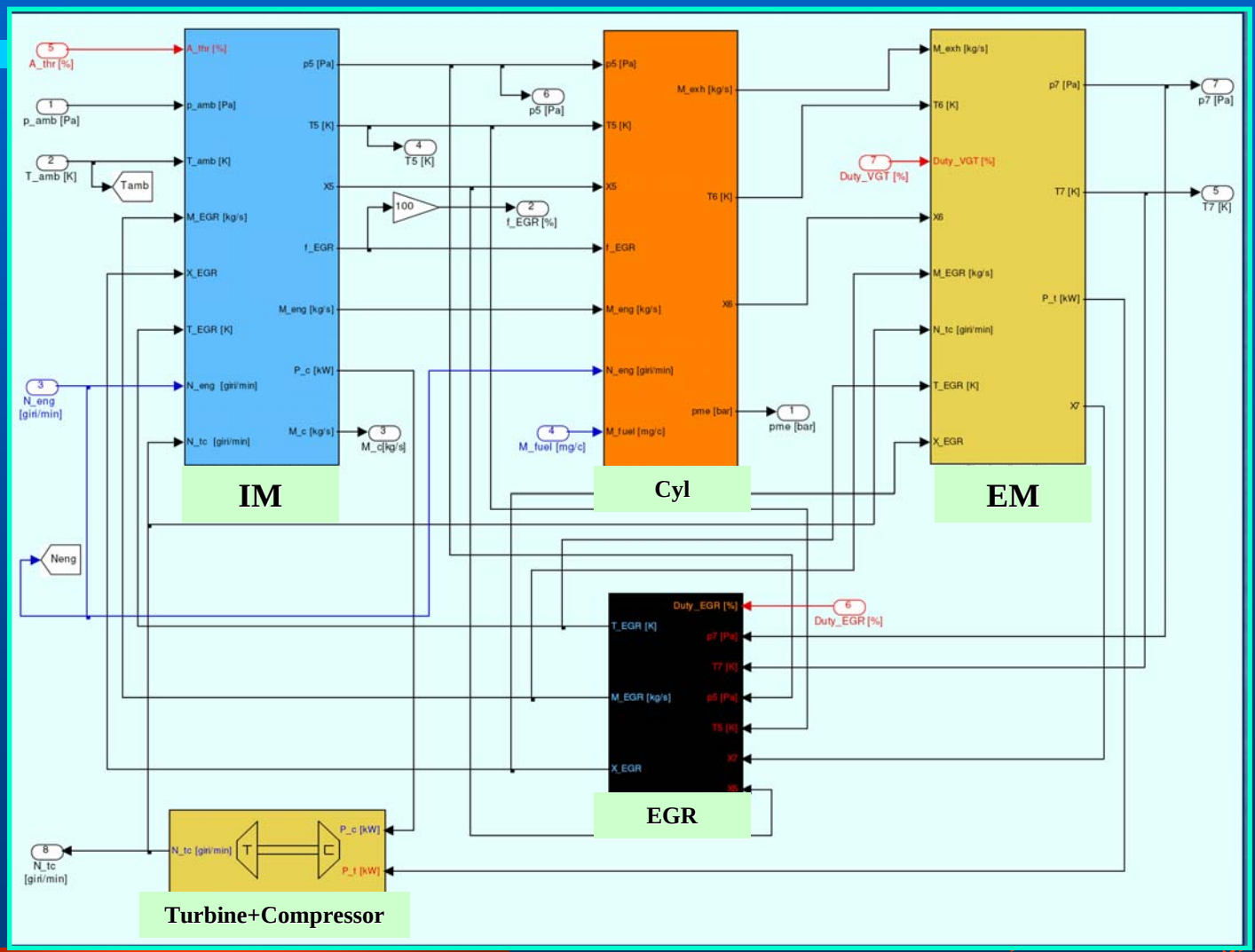
Project Details: Overview

- Design of a control scheme for commercial diesel engines (boats, ships, farm tractors, …)
  - Diesel engine modelling
    - black-box: fuzzy modelling
    - grey-box: analytical approach
  - Control system strategy
- Electronic Control Unit (ECU)
  - Control scheme on-board real implementation

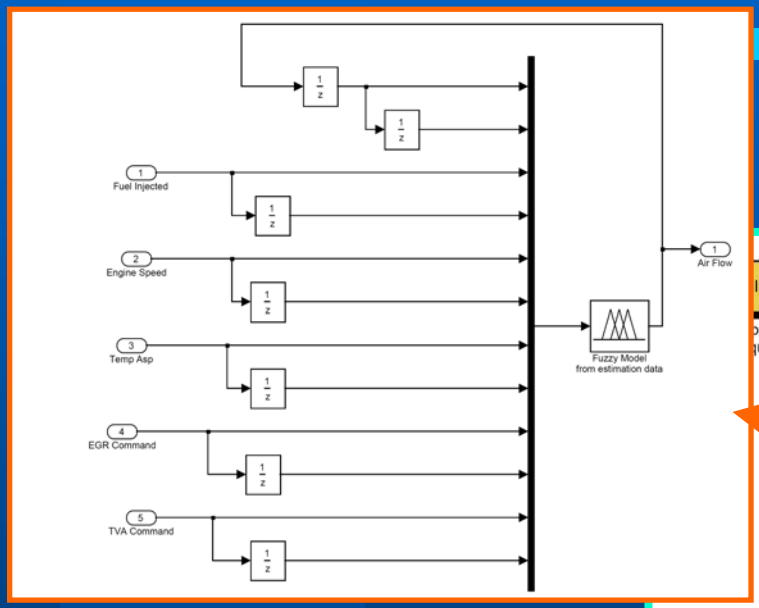
NO_x & PM Control Strategy



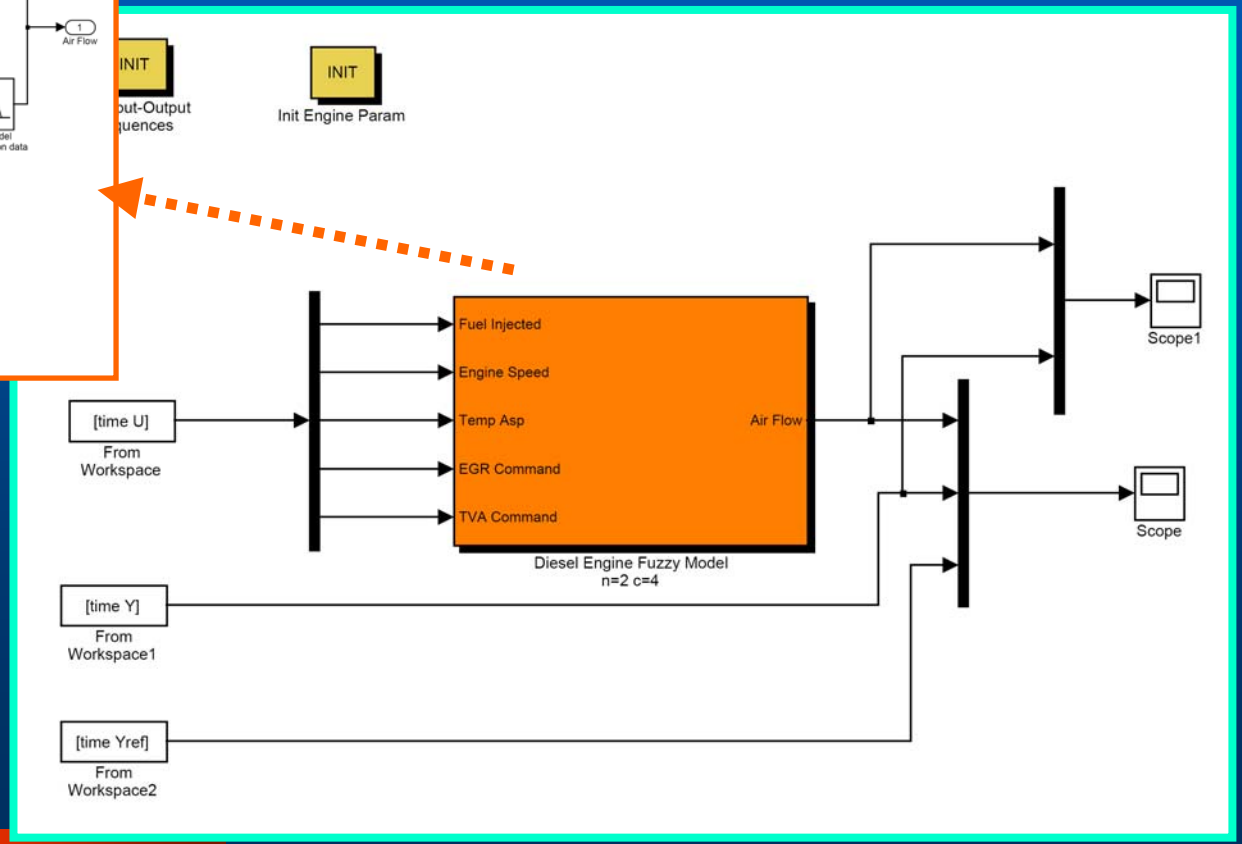
Engine Complete Description



Identified Fuzzy Model

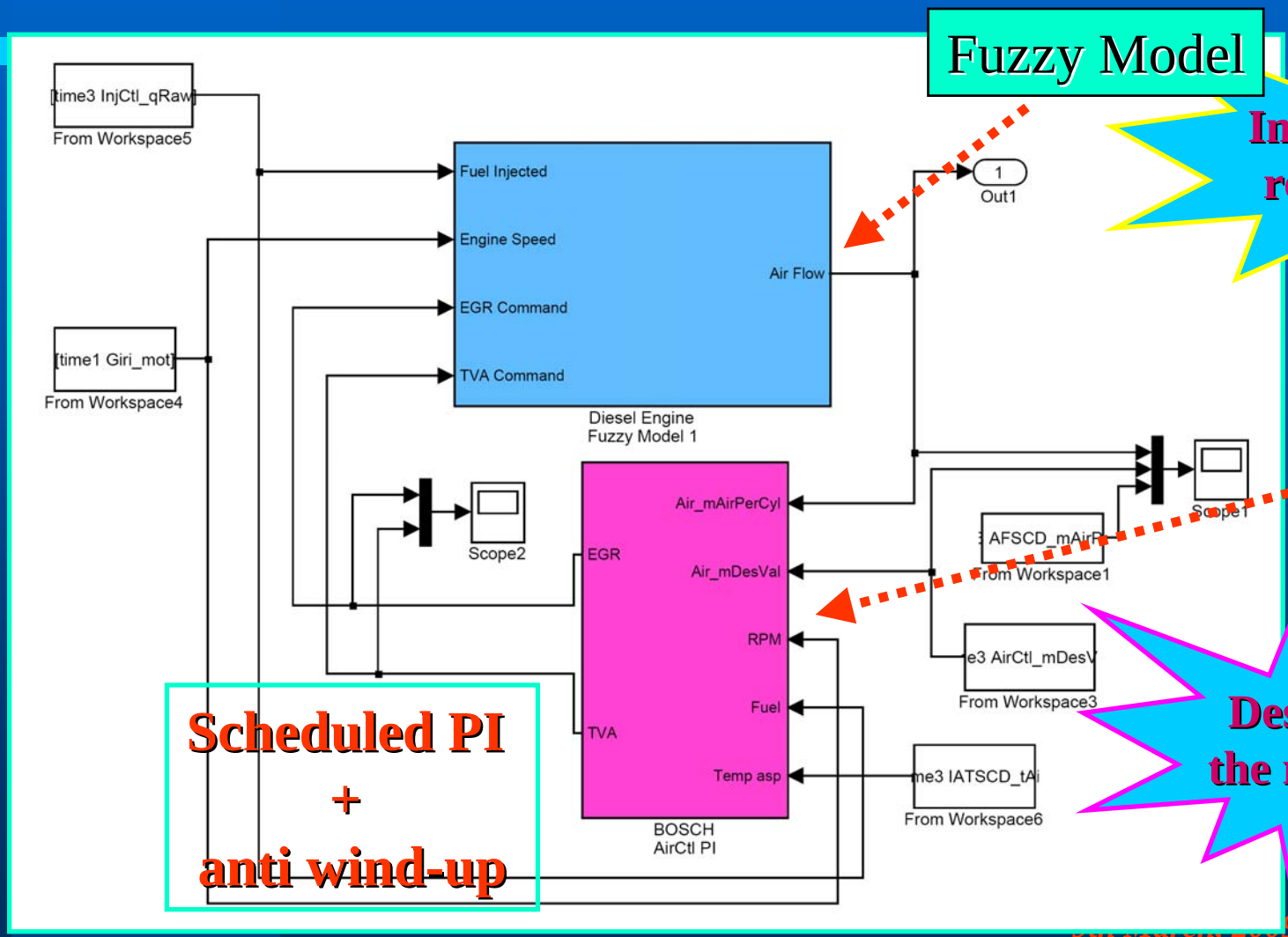


- Local model order: $n = 2$
- Cluster number: $c = 10$

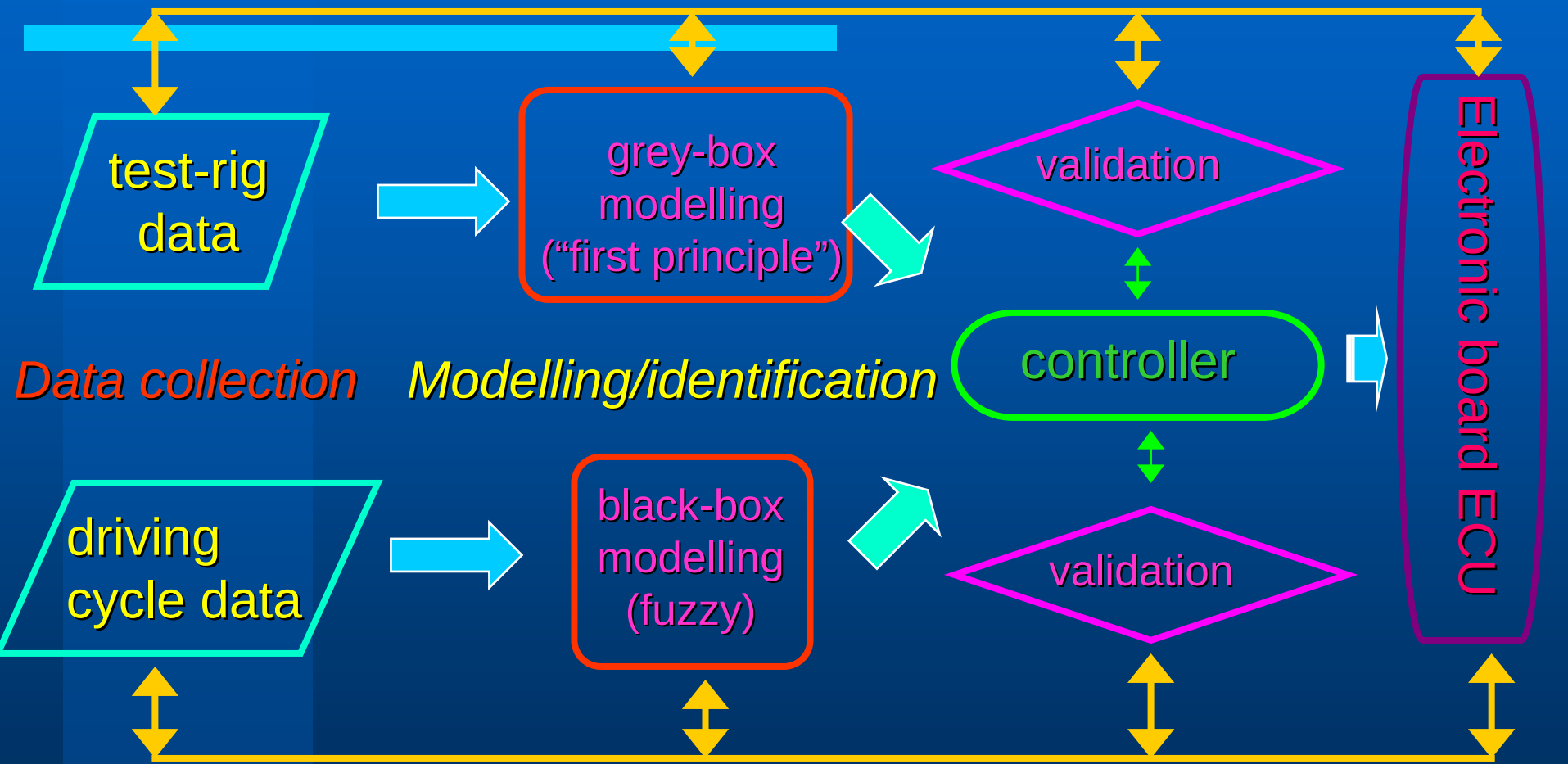


c & *n* optimised via a PEM iterative scheme

BOSCH Controller Tuning



Project "FlowChart" Scheme



Project (1) Achievements

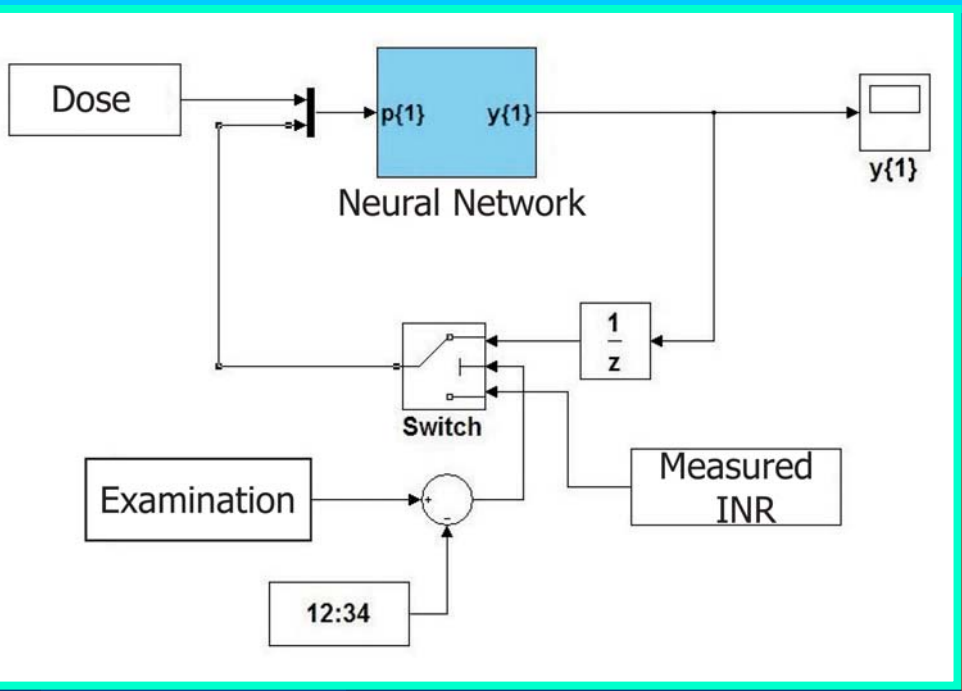
- Control-oriented simulation model
  - Black-box engine model from real data (driving cycles)
  - Grey-box model from real data (test-rig engine system)
- Automatic software (GUI) for model identification & controller calibration/fine tuning
- Further applications: diesel engine FDD/FTC?
  - Actuator & sensor faults?

Computerised Decision Support Systems for Oral Anticoagulant Treatment (OAT) Dose Management

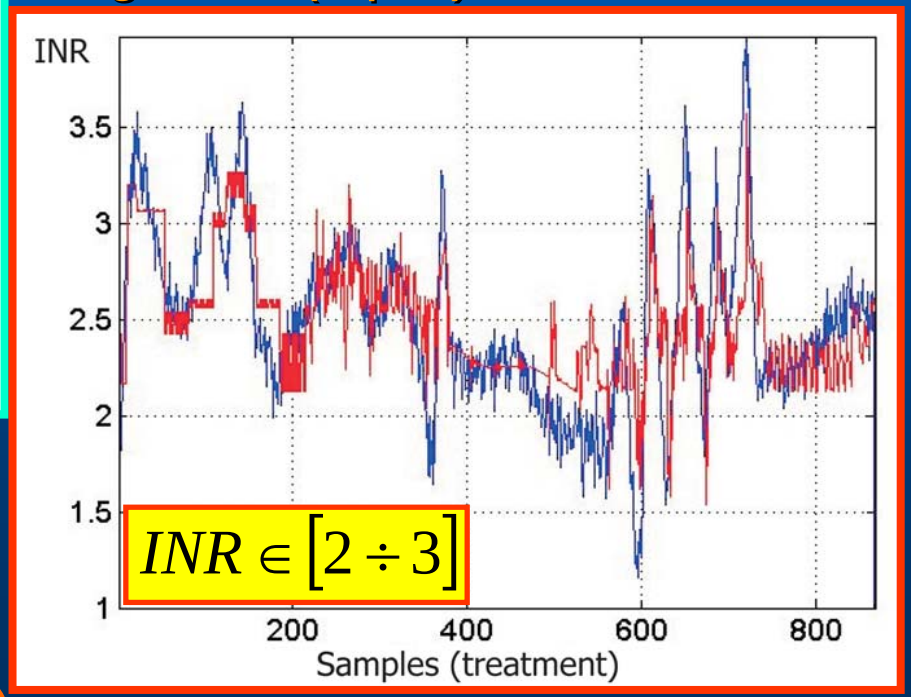
Decision Support for OAT

- Decision support in anticoagulation drug therapy
  - Used to learn the prescribing behaviour of expert physicians/clinicians or alternatively to learn the outcomes associated with such decisions
- Anticoagulant drug therapy inhibits or delays coagulation of the blood
  - INR (International Normalised Ratio): international standardised method of reporting a patient's prothrombin time (the time it takes for the patient's blood to clot).
  - Drug therapy prescription based on statistical analysis (*i.e.* model-free approach)

Neural Network Model

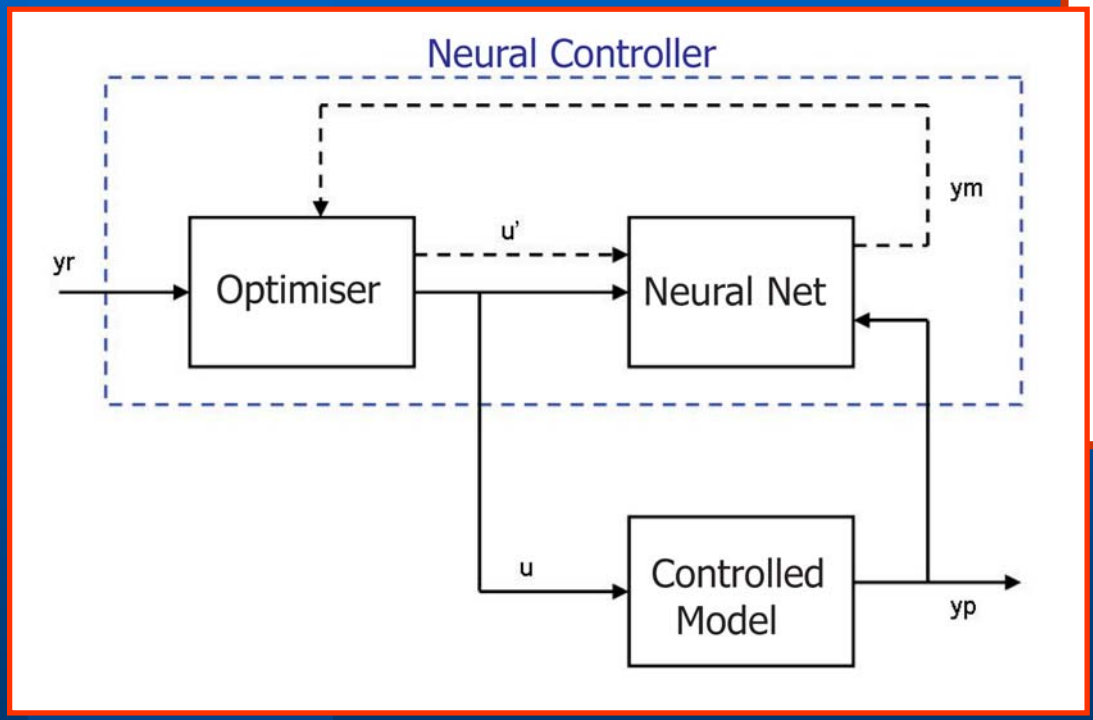


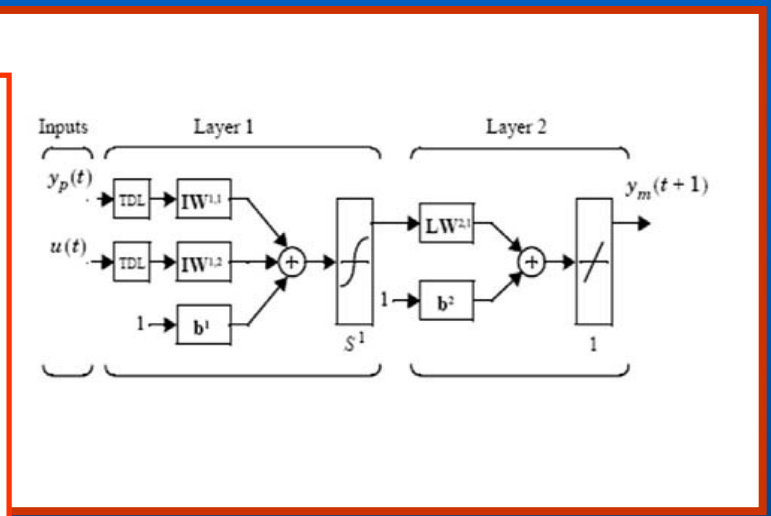
Dynamic neural network to predict human body behaviour (INR, output) w.r.t. prescribed drug dose (input)



INR target values for people undergoing OAT depend on pathology (transplants, heart diseases, apoplectic fits, …)

Model Predictive Control





$$J = \sum_{j=N_1}^{N_2} \left[y_r(t+j) - y_m(t+j) \right]^2 + \rho \sum_{j=1}^{N_u} \left[u'(t+j-1) - u'(t+j-2) \right]^2$$

Neural controller used for predicting the OAT drug dose depending on the human body NN model (drug dose – INR value)

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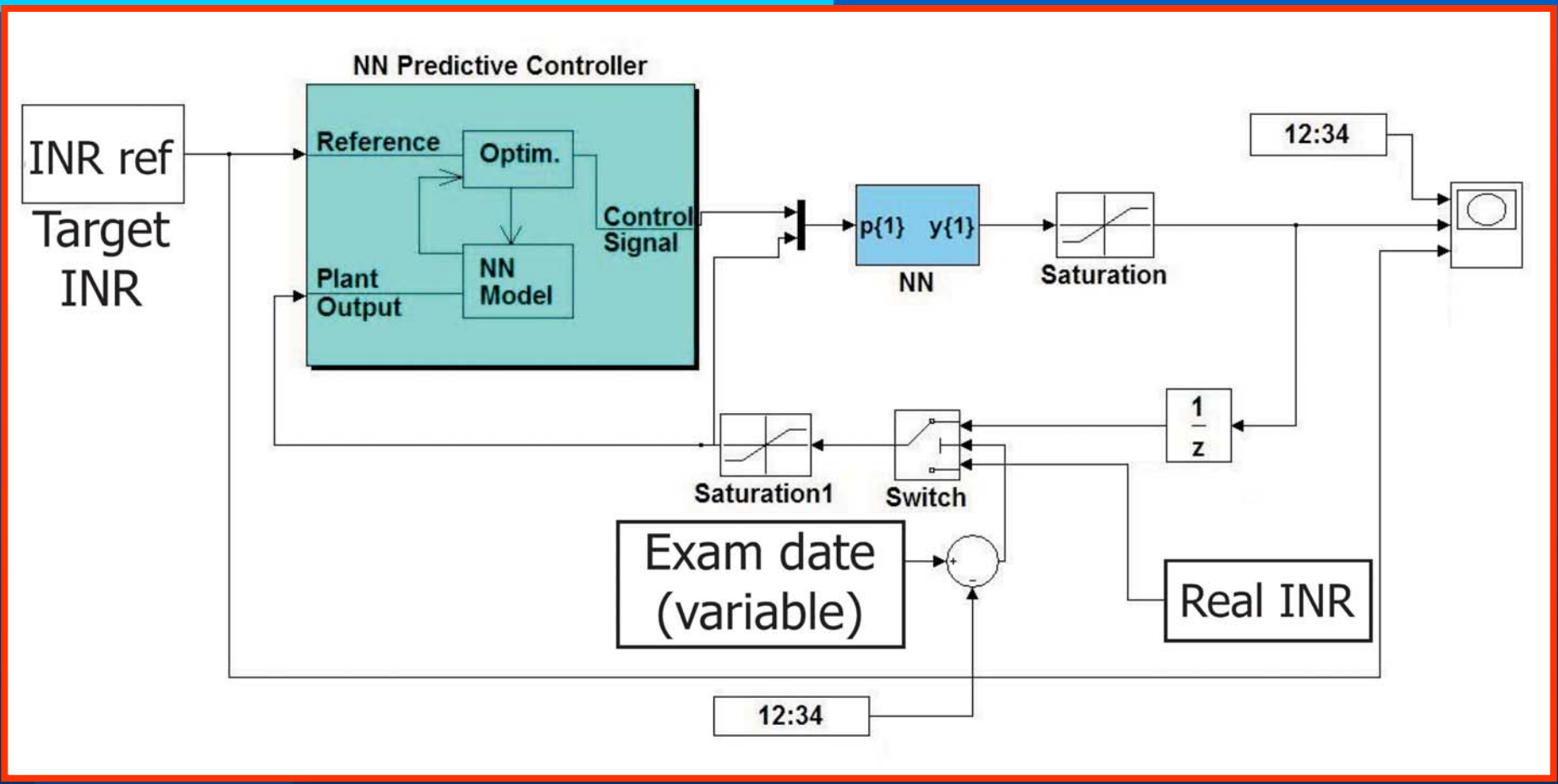
Final Tool: NN PC (Simulink)



Project (2) Achievements

- Automatic strategy for oral anticoagulant therapy dose adjustment
- NN modelling & control strategy
- Help for medical practitioners & traditional medical OAT drug dose prescription tools
- Implementation automatic software tools of portable electronic devices (“e-care”)
- Patient self management of oral anticoagulant drug therapy

Development of Fault Tolerant NGC (Navigation, Guidance & Control) Algorithms for CUAV (Civil Unmanned Aerial Vehicle) Patrolling & Rescue Missions in Harsh Environment

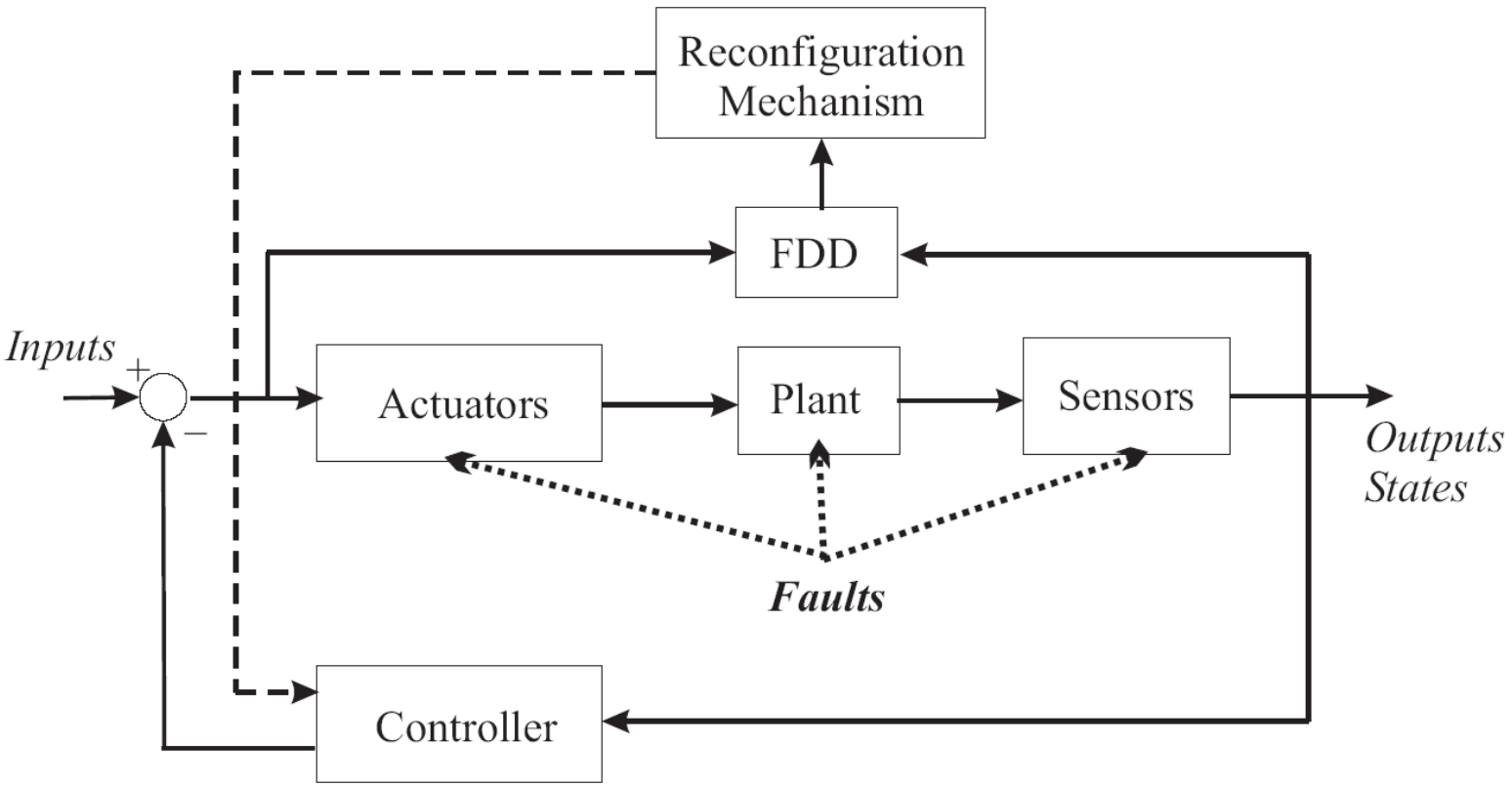
Project Details

- CUAV demonstrator development (ultra-light aircraft)
- Guidance, navigation & control (GNC) algorithm testing for trajectory tracking
- Fault diagnosis (FDD) and fault tolerant control (FTC) algorithm designs

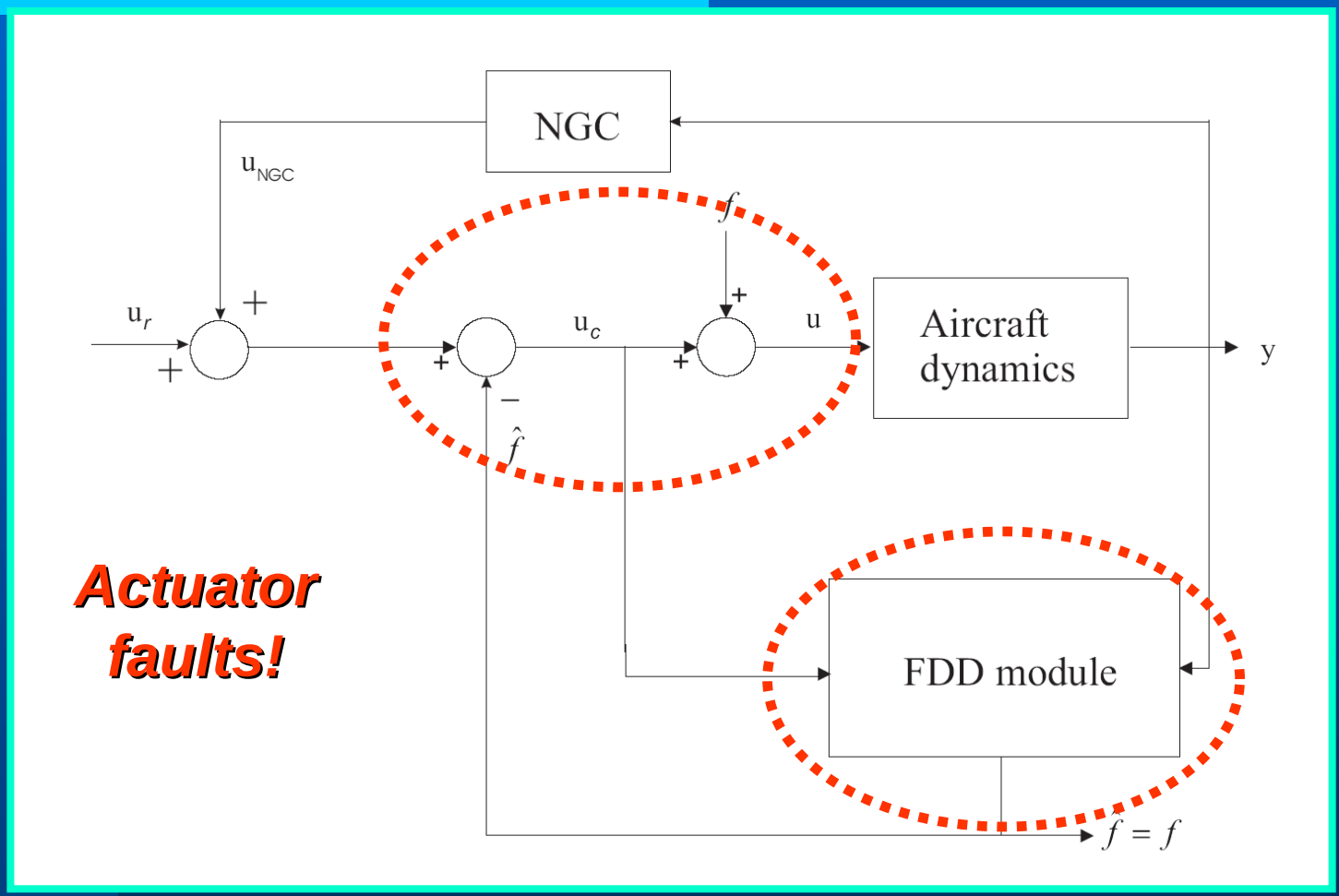
Project Details (cont'd)

- Increased payload (60-70 kg versus 3-4 kg)
- Pilot available on-board (much longer flying distance)
- Take off from any aerial space & from small civil airports
- Ultra-light aircraft does not requite strict aeronautic regulations, homologation, maintenance, …
- Real fault testing, generated on-board with electronic & electro-mechanic devices (*e.g.* clutches, …)

AFTCS General Structure



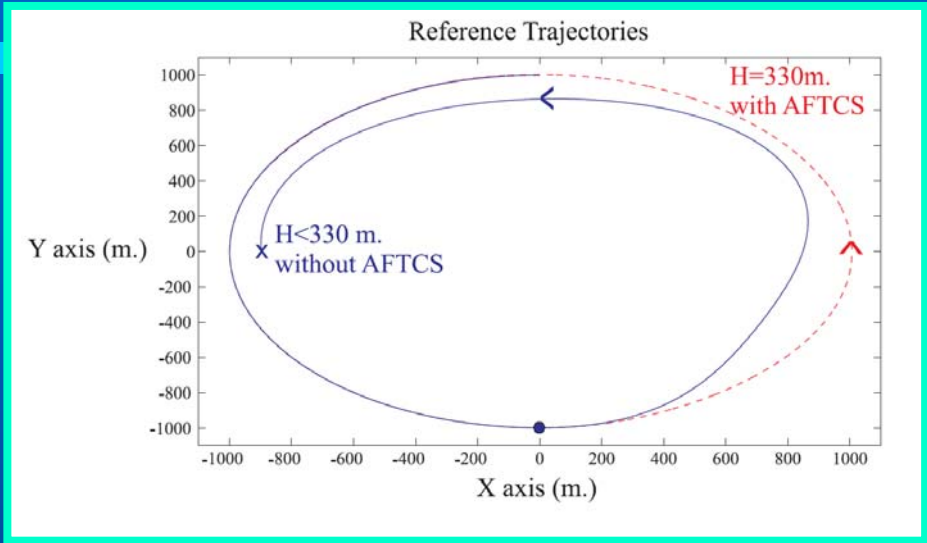
Integrated AFTCS Strategy

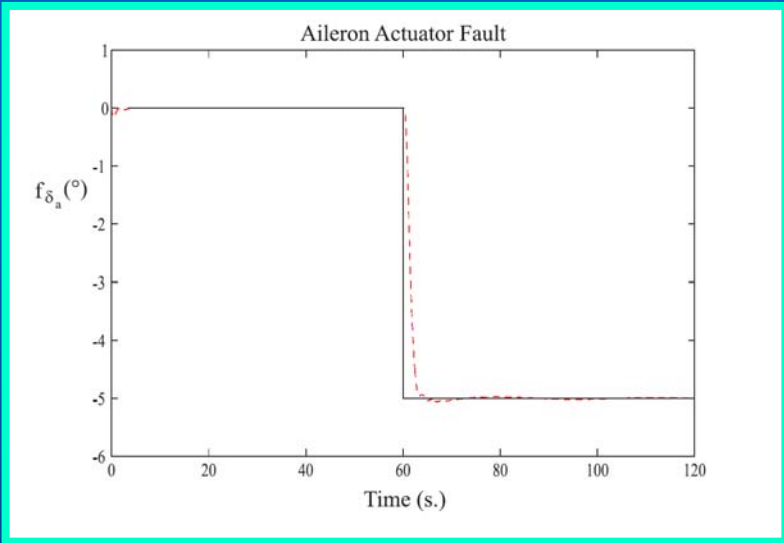


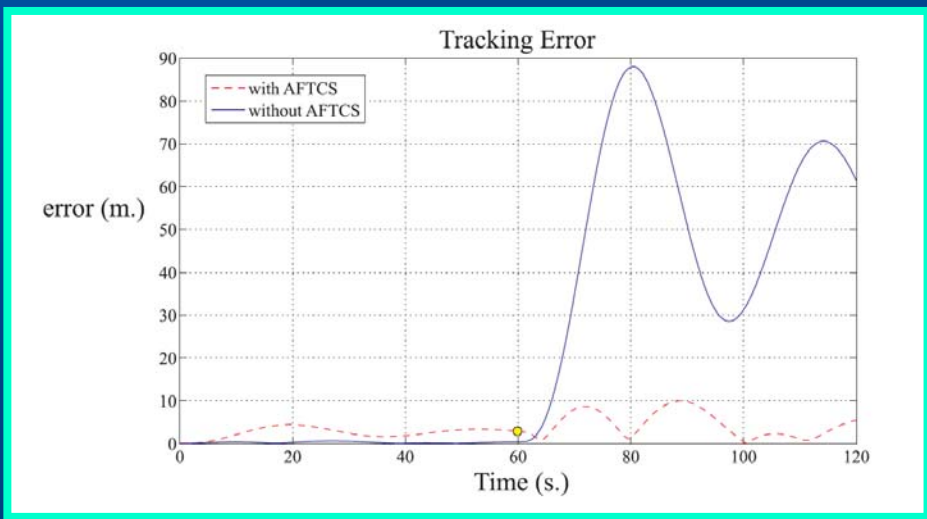
Integrated AFTCS Modules

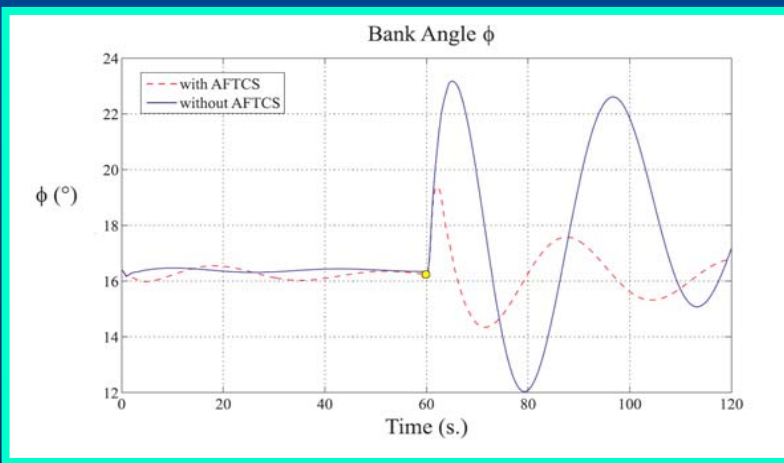
- FDD scheme
  - Non-linear adaptive filters for disturbance de-coupling (NLGA-AF)
  - Particle filters (NLGA-PF)
- FTC scheme
  - Controller reconfiguration
- Simulation aircraft non-linear model
  - GNC controller

Simulated Results (Civil Aircraft)









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Project (3) Achievements

- Non-linear high fidelity aircraft model
- GNC tests
- Preliminary FTC design, performance analysis & simulation assessment
- Actuator/sensor fault simulated effects
- Flying quality enhancement, asymptotic fault accommodation, & control objective recovery.