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Model-Based Fault Detection and Isolation Design for Flight-Critical Actuators in a Harsh Environment

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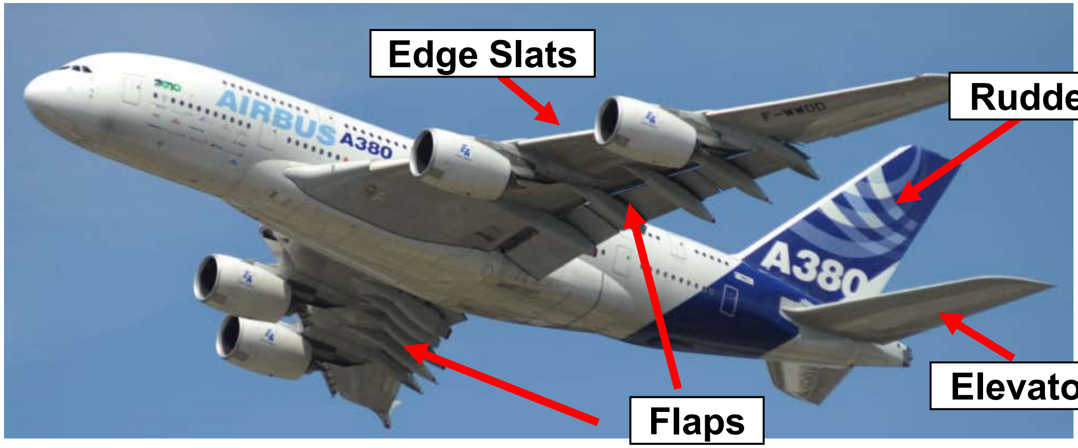
ESTIA RECHERCHE
CCI BAYONNE PAYS BASQUE

- **Technological Background**
- **Problem and Solution Statement**
- **Case study: Fault Detection on an Electromechanical Actuator (EMA)**
- **Results**
- **Conclusion & Perspectives**

TECHNOLOGICAL BACKGROUND

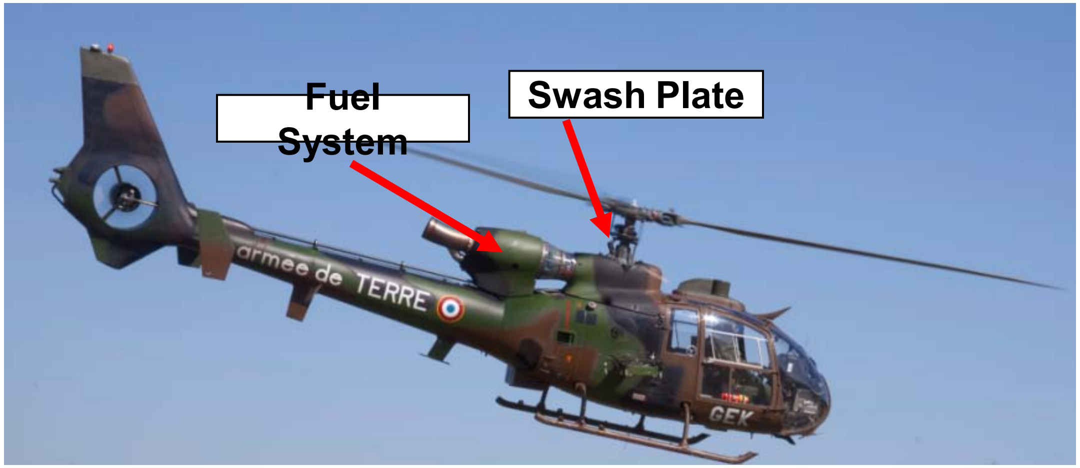
Actuators in Aircrafts are used for:

- Flight control
- Force Feedback (Pilot)
- Engine Control
- Landing Gears



Actuator Types

- EMA
- EHA



Actuators are Part of flight critical systems

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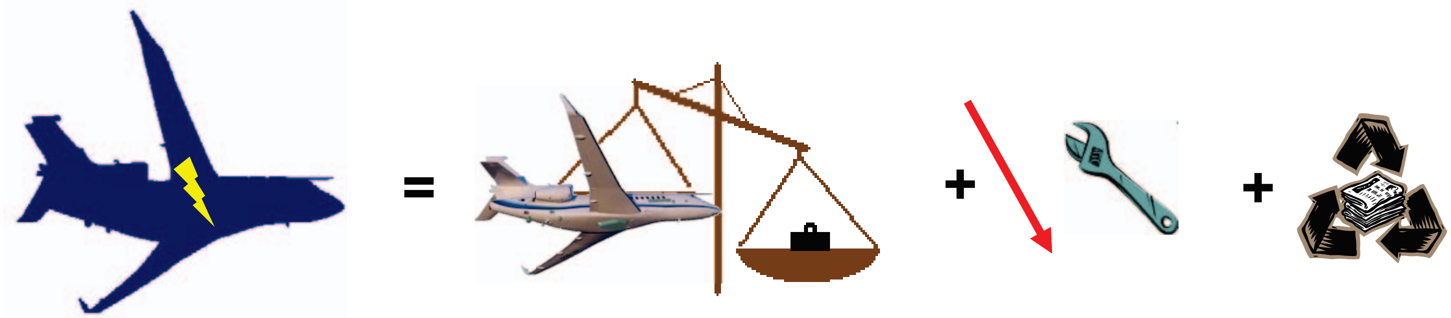
PROBLEM AND SOLUTION STATEMENT

Aims of the More Electric Aircraft :



Need:

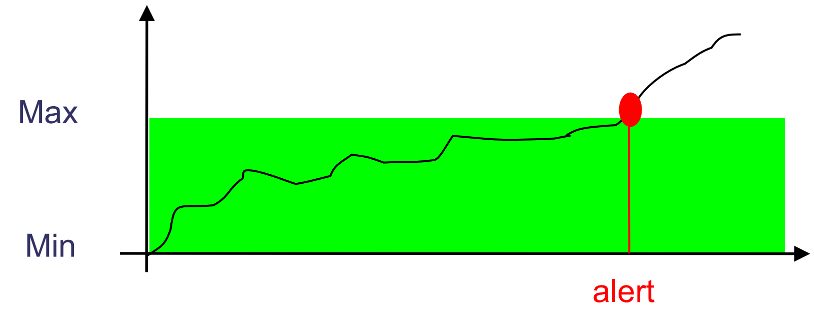
- **Gain of mass and Space through:**
  - Replacing Low-Power Pneumatic or Hydraulic Systems
  - Simplifying Architectures (less material redundancies)
  - Sensorless System Control
- **Reducing Maintenance Actions**
- **Better System Monitoring**
- **Increase of Fault Detection & localisation on Flight Critical Systems**

Replacement of Low Powered Hydraulic Actuators (<10kW)

PROBLEM AND SOLUTION STATEMENT

Fault Detection Methods Applied to Actuators in Current Aircrafts:

- Limit checking
- Material Redundancies



ri = residuals

Si = sensors outputs

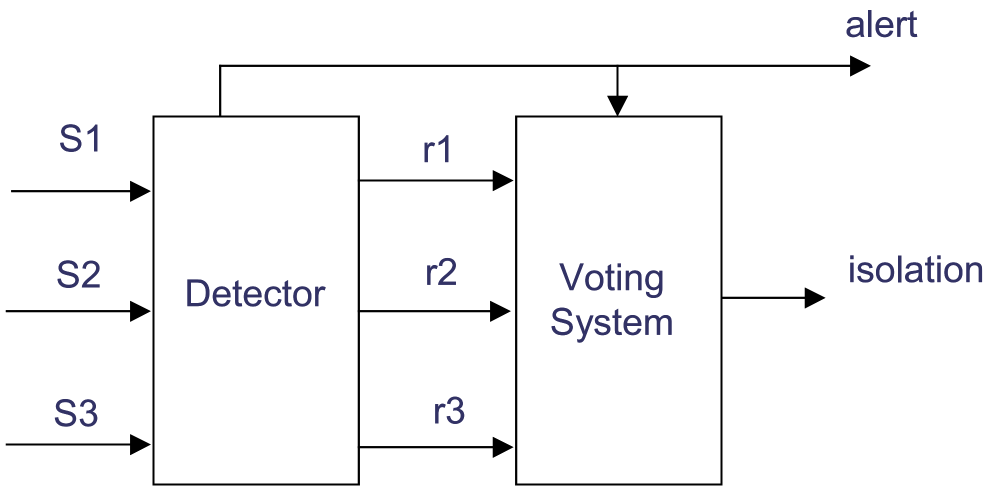
r1 = S1-S2

r2 = S1-S3

r3 = S2-S3

If r = 0 then OK

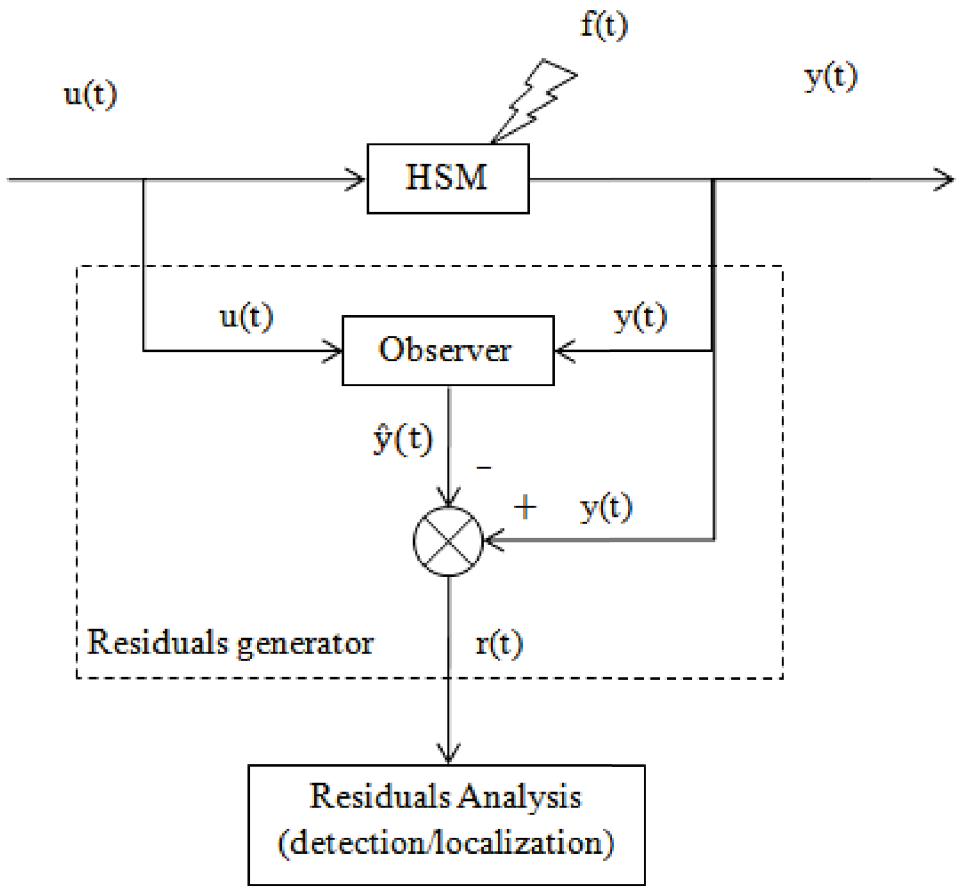
If r <> 0 => default on previous sensor



Need of Fault Detection Methods for nonlinear Systems

Model Based Fault Detection

- Analytical Redundancy = Less Sensors thanks to Parameter Reconstruction



The Model (Observer) Takes into Account The System's Nonlinearities

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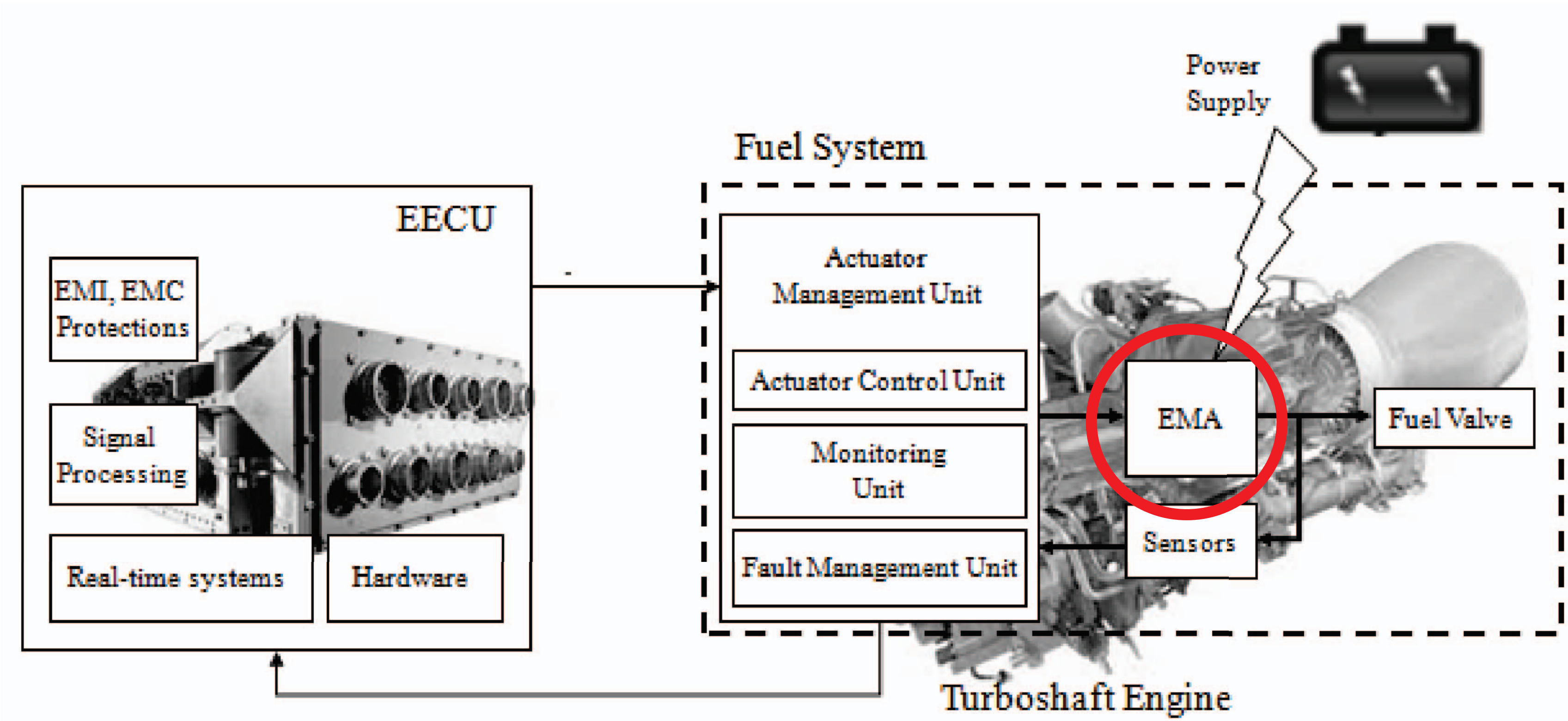
CASE STUDY: FAULT DETECTION ON AN EMA

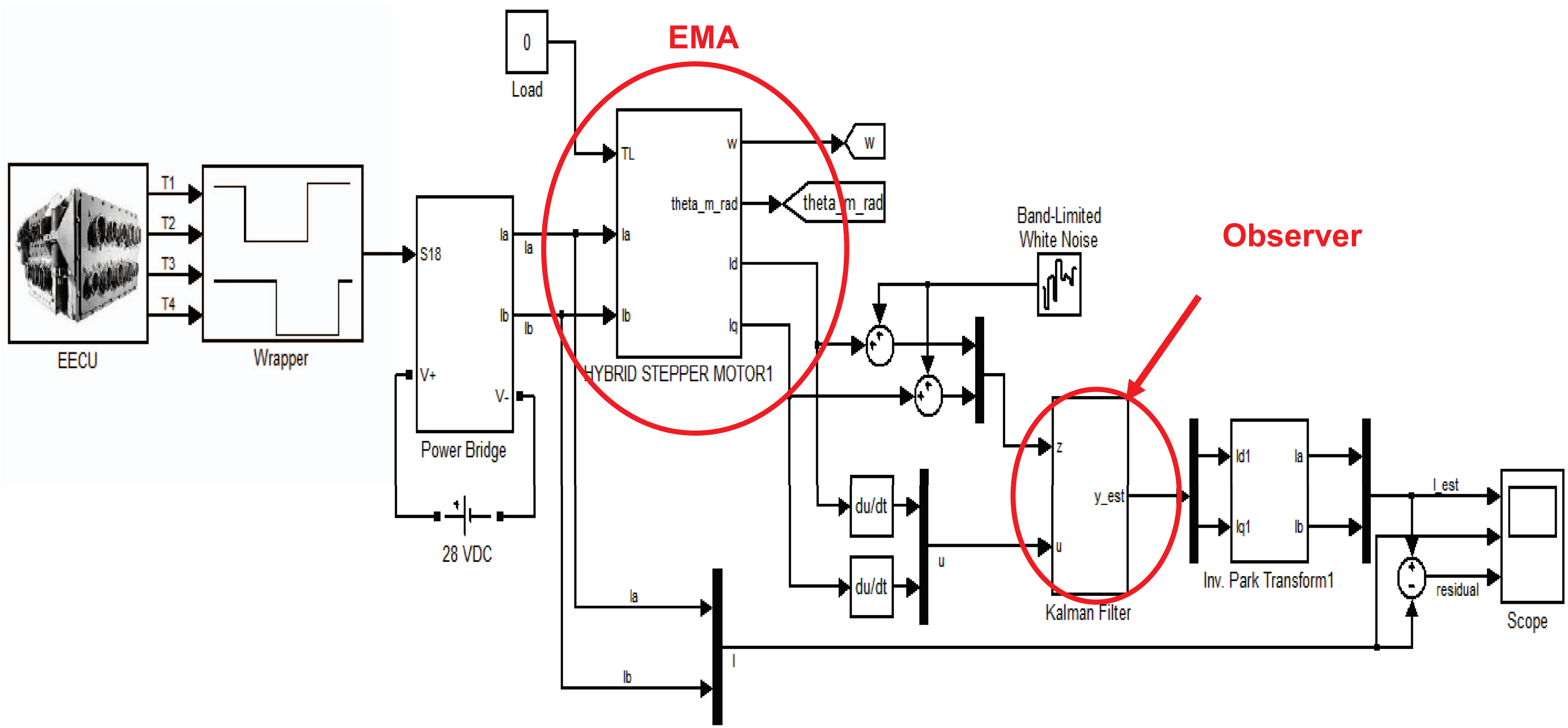
Hybrid Stepper Motor Used in a Fuel System of a Turboshaft Engine



HSM = Nonlinear System => Need of a Nonlinear State Space Model

CASE STUDY: FAULT DETECTION ON AN EMA

Simulation Model



The HSM Model is linearised to fit with a Standard Kalman Filter

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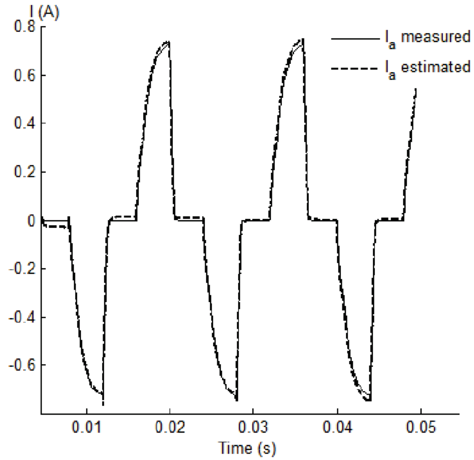
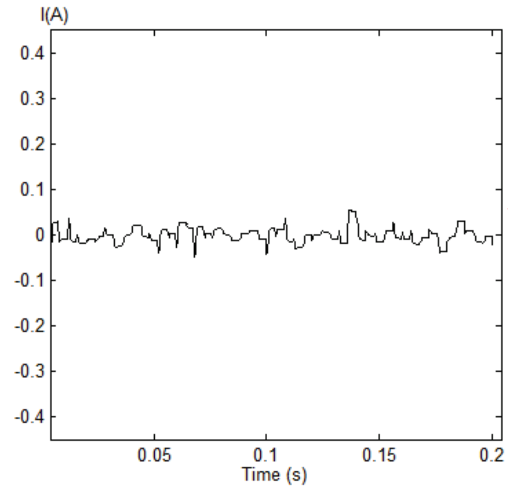
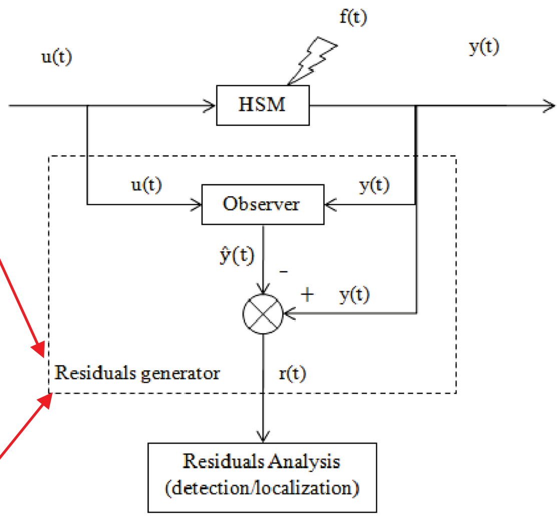
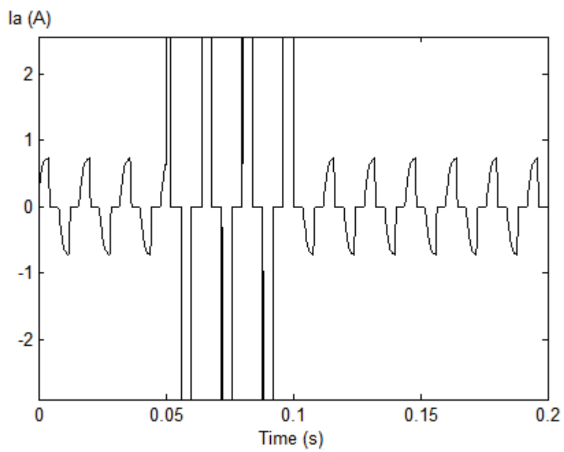
Current in Phase *Ia* Without Faults

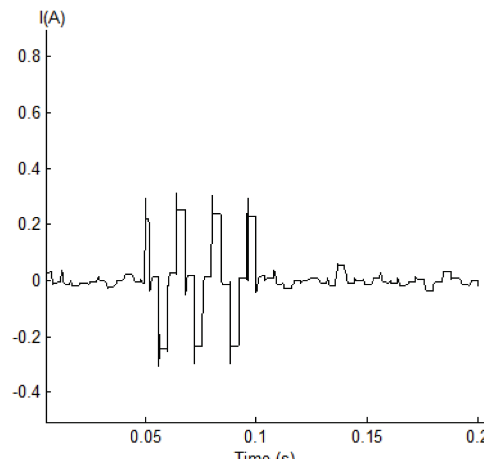






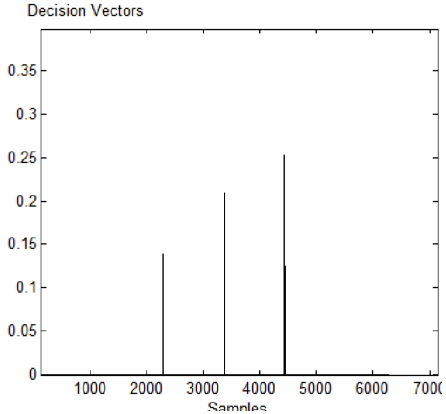
Fault Occurrence: Short Circuit on Phase *Ia*



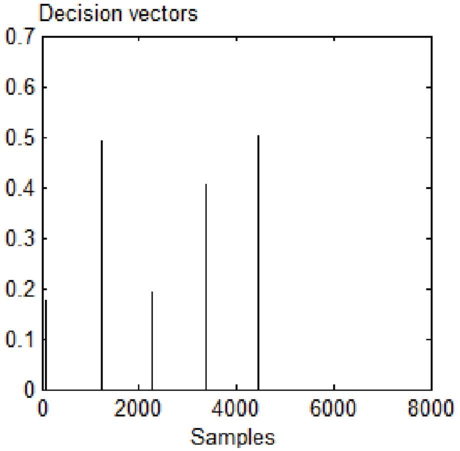


Fault Occurrence Appears on the Residual Signal

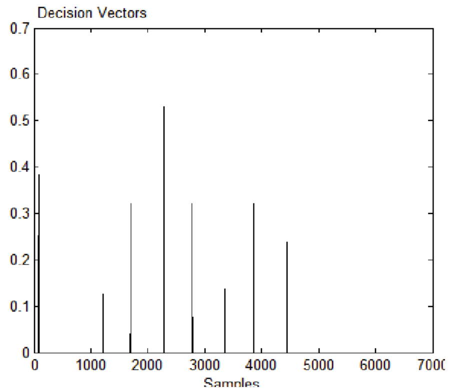
Fault Detection on the Residual Mean Change : CUSUM Method



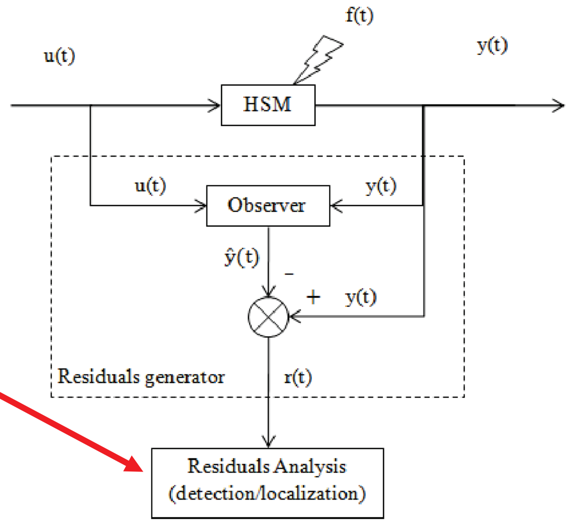
m1 = 0.4 ; λ = 0.6



m1 = 0.3 ; λ = 0.6



m1 = 0.2 ; λ = 0.6



False Alarms and Non-Detections Depend on m1 and *λ values*

The Kriging Method:

- **Allows to find values of m1 and λ in order to:**
  - Increase the performances of the CUSUM test by minimizing false alarm and non-detetction rates

Y= cost, needs to be minimized

$$Y = f_d + n_d \quad \Rightarrow \quad Y(x) = f(x) + z(x)$$

False Alarm Rate (f_d)

Non - Detection Rate (n_d)

Regression Function (f)

Hyperparameters (m1 and λ) (x)

Correlation Function ($z(x)$)

The aim is to find the values of m1 and λ that minimize *Y*

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CONCLUSION & PERSPECTIVES

- **Model Based Fault Detection Approaches Increase Safety in Flight Critical Systems by minimizing False Alarms and Non-Detection Occurrences**

- **It is a Validation Criteria for Flight Critical System Designs, required by Aeronautical Standards [ARP 4754 / 61]**

- **Model based Approaches is a Solution for reducing material Redundancies in Aircrafts**

- **Compared to limit-checking or mean-checking methods, Observer-Based Approaches take into account the Nonlinearities of the Model**

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Any Questions?