GENeric diagnosis Instrument for SOFC Systems (245128)

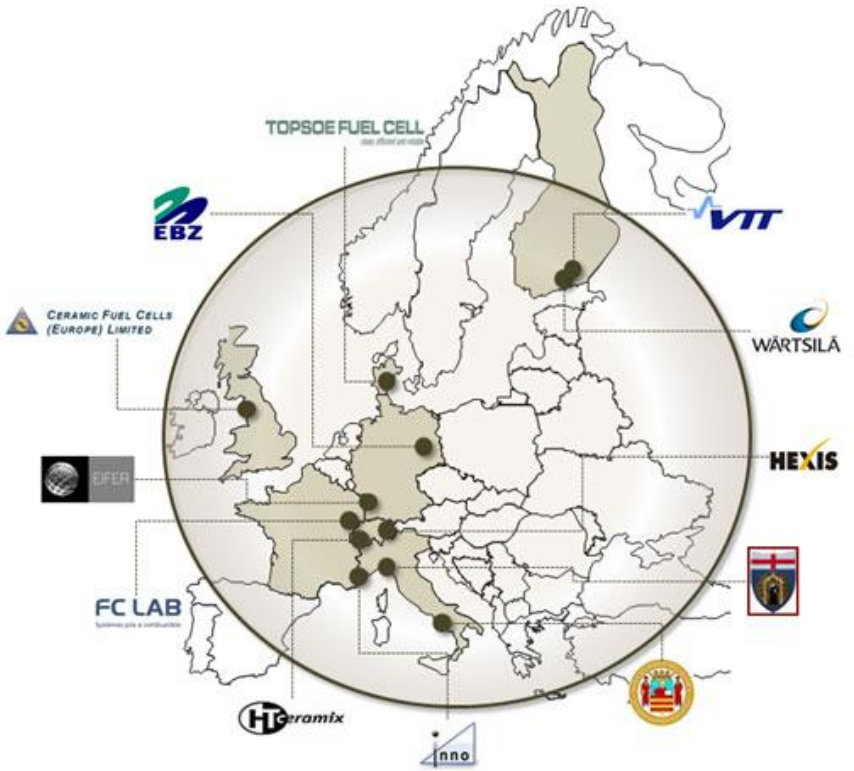
Philippe MOÇOTÉGUY
EIFER/Project Manager

Genius Partnership & Budget

3 years collaboration project: 01-02-2010 to 31-01-2013

Total budget: 3928 k€ ; Total funding: 2068 k€

Participant	Country	Type
EIFER	Germany	R&D
CFCL	England	Industry / SME
EBZ	Germany	Industry / SME
FC LAB	France	University
Hexis	Switzerland	Industry / SME
HTc	Switzerland	Industry / SME
TOPSOE	Denmark	Industry / SME
UniGE	Italy	University
UniSA	Italy	University
VTT	Finland	R&D
Wärtsilä	Finland	Industry / SME
Inno	France	Industry / SME



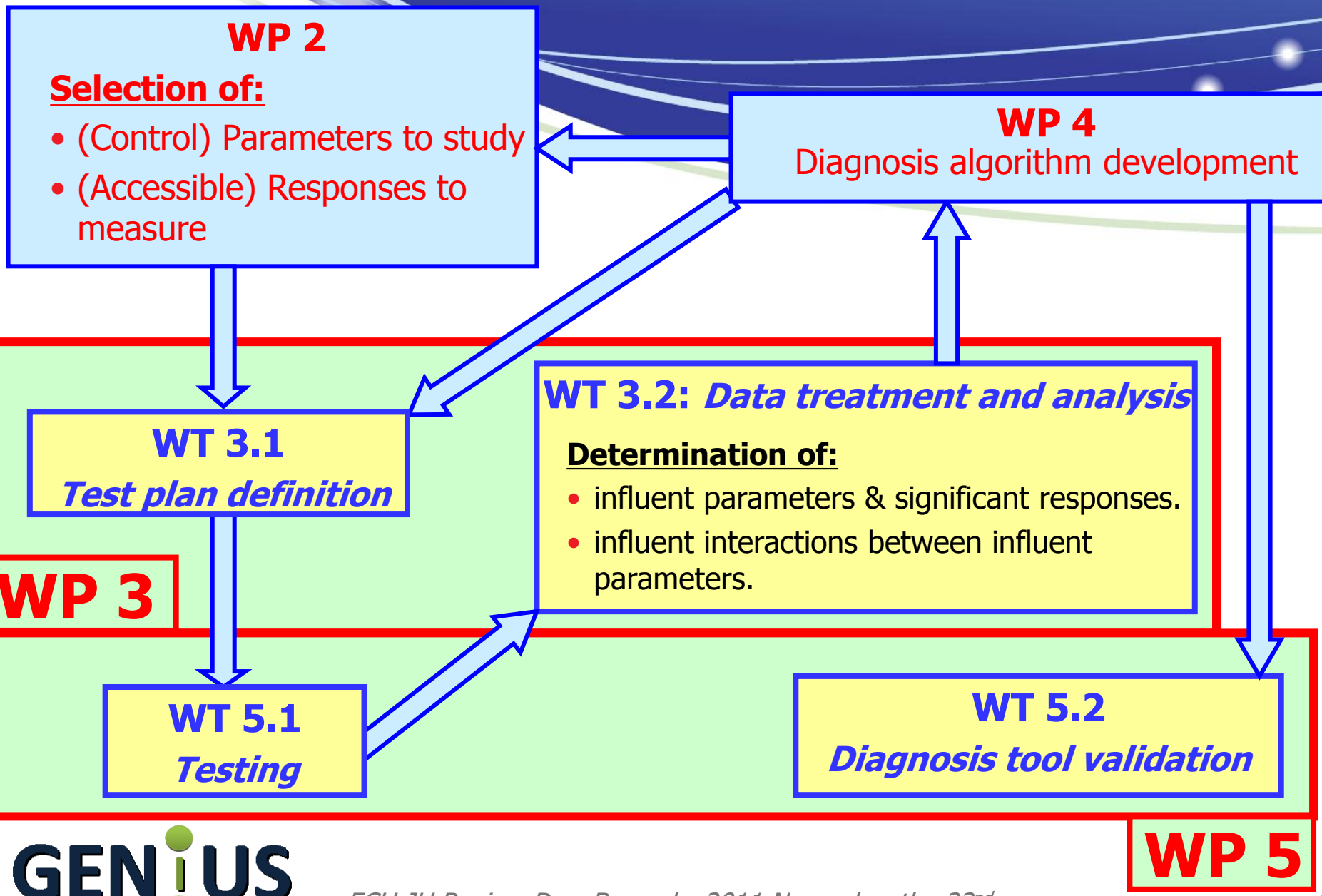
A European dimension with
a good balance between academics, R&D centres and industries

Objectives

Develop a "GENERIC" diagnosis tool by:

- Testing stacks & systems from 4 manufacturers, using commonly defined test plan based on "Design Of Experiment" methodology.
- Evaluating 3 different types of models by 4 different academic institutions in order to define the optimal tool for fault detection and identification taking into account "on board" and "off-line" constraints.
- Developing a diagnostic hardware that will integrate the best algorithm and validate it on two different SOFC systems,
- Correlating physical parameters and degradation mechanisms. **(interaction with DESIGN project)**

Project structure

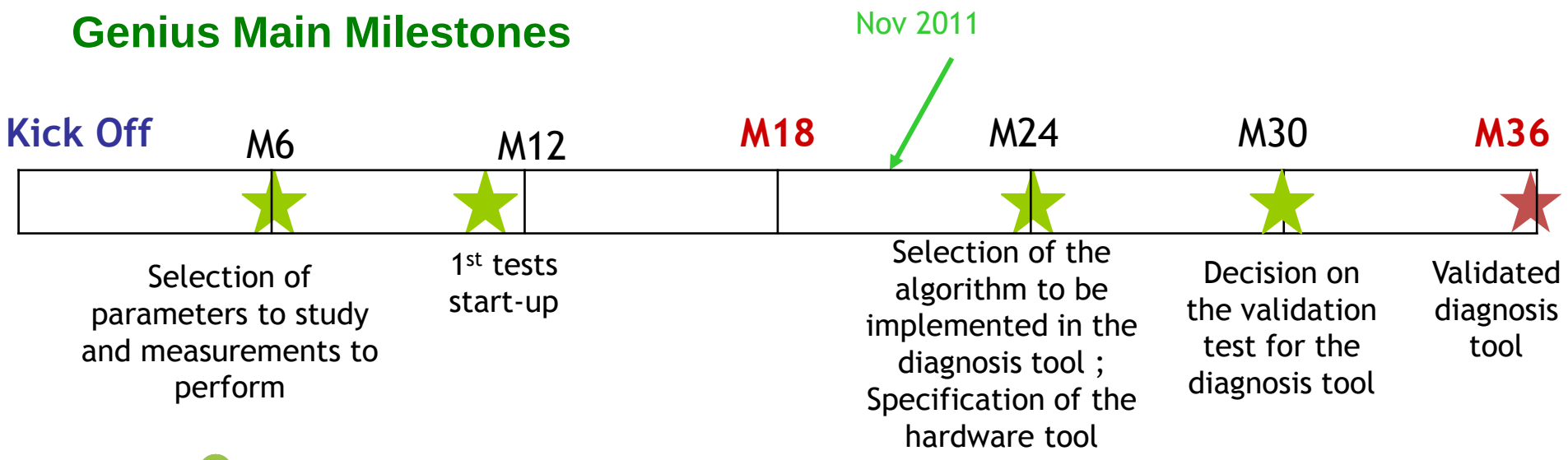


Genius Outcomes & Milestones

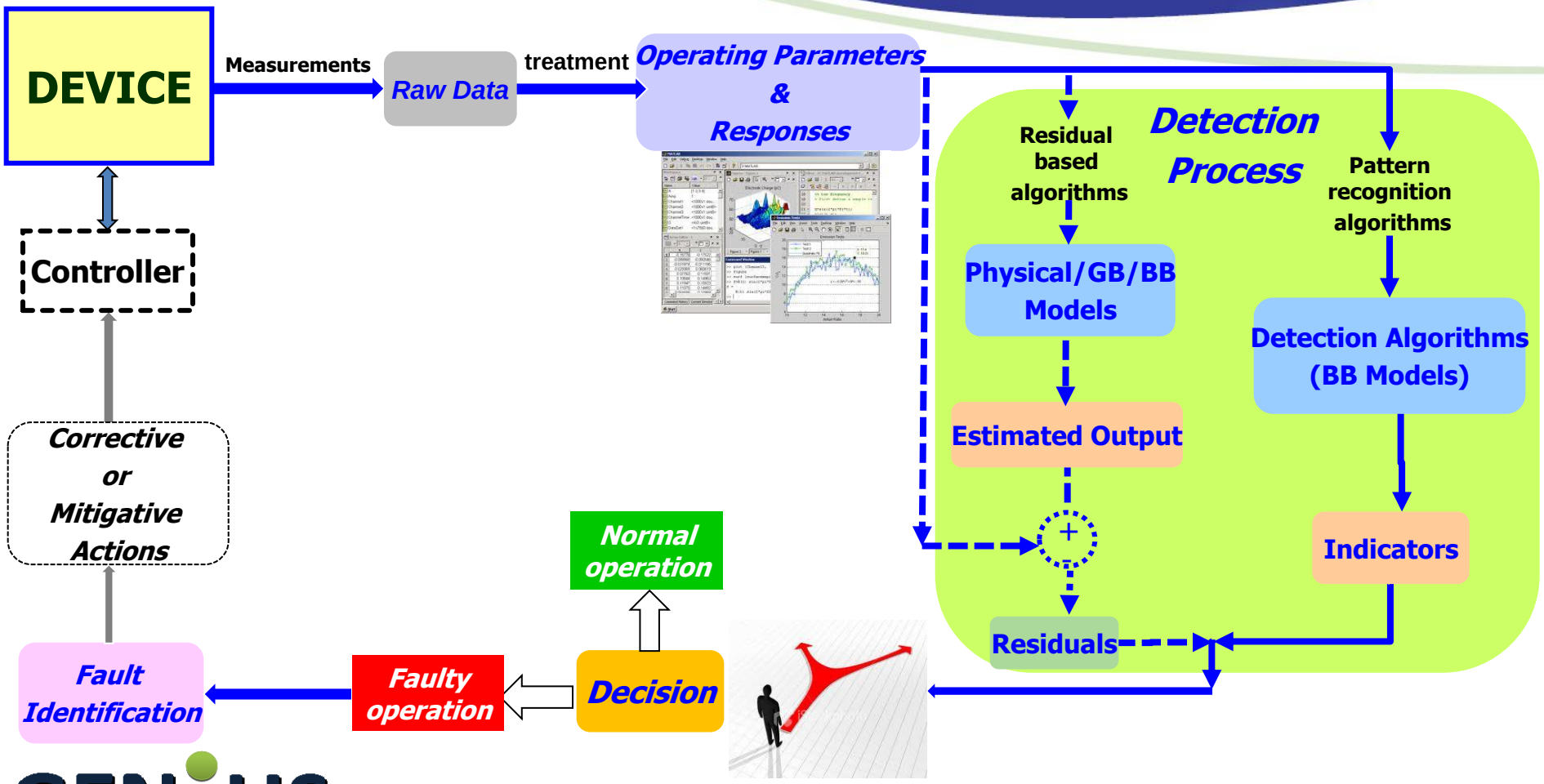
Genius Outcomes

1. Development of algorithms based on 3 different methodologies: Comparison of their performance and identification of the most efficient algorithm, evaluation of the interest in combining several methodologies to improve diagnosis reliability;
2. Caracterisation of stack/systems from 4 different manufacturers: algorithm's "genericity" evaluation";
3. Final validation of an integrated hardware/software diagnosis tool in 3 different systems;

Genius Main Milestones



WP 4: Diagnostic methodology



Supplied and tested stacks and systems during development phase

Galileo®
HEXIS's system
tested by **EIFER**

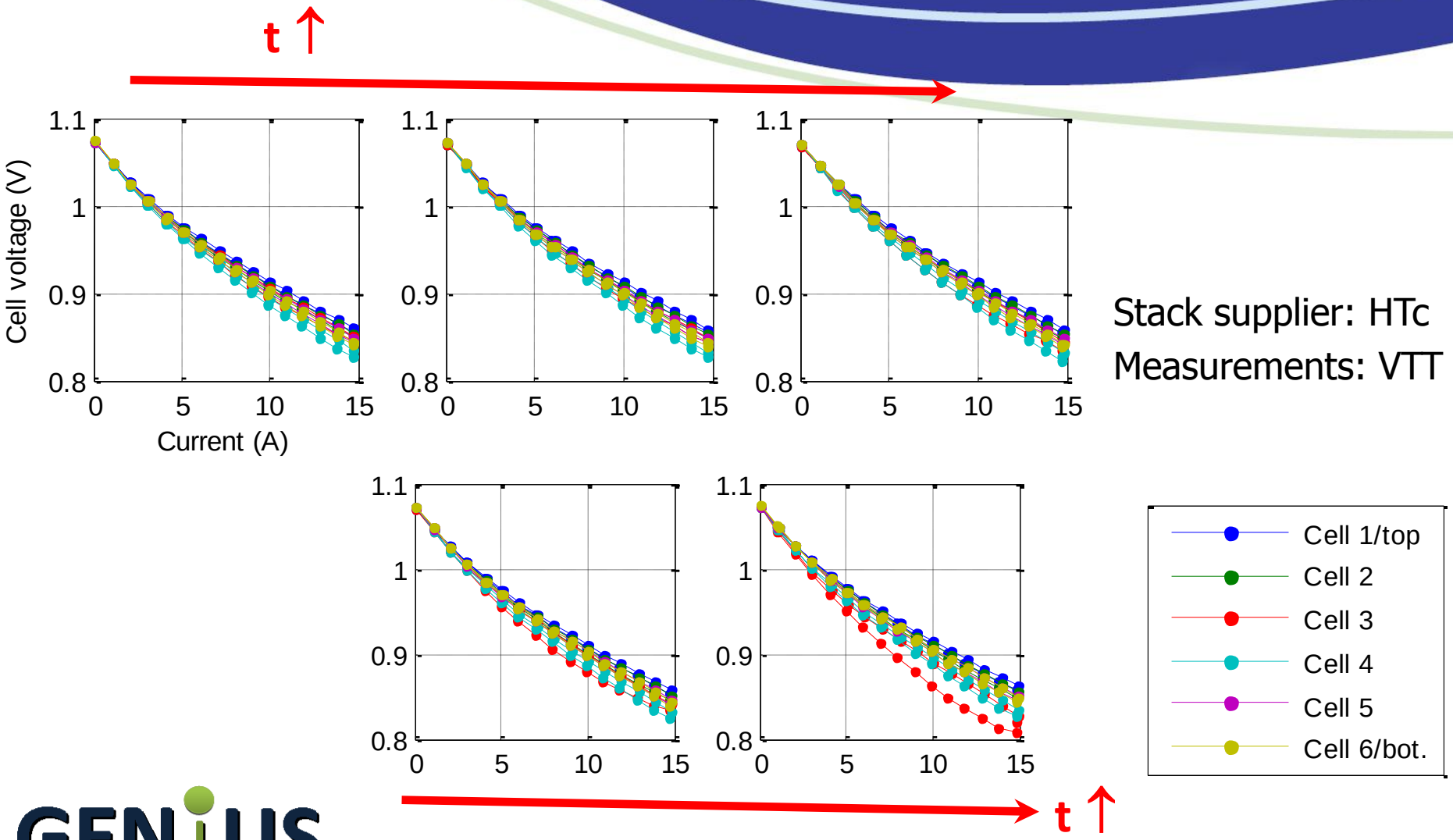
TOPSOE FC: stacks
tested by **TOPSOE FC**

HTc short stack
tested by **VTT**

CFCL systems
tested by **CFCL**

GENIUS

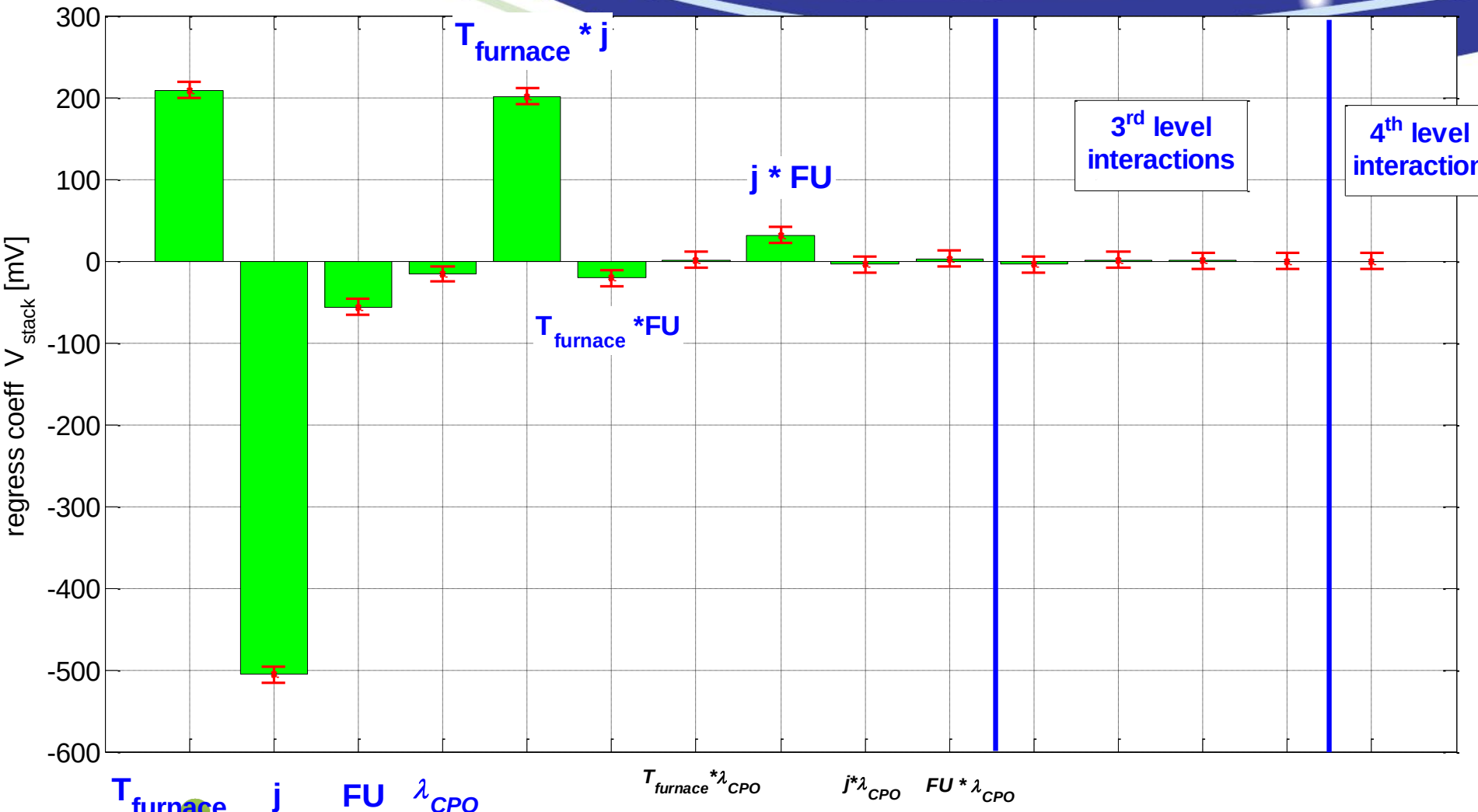
WT 5.1: Evolution of HTc stack's U=f(j) curves with "ageing"



Stack supplier: HTc

Measurements: VTT

WP 3: DoE analysis of stack voltage (VTT experiments on HTc stack)



WT4.1: Black box models approach

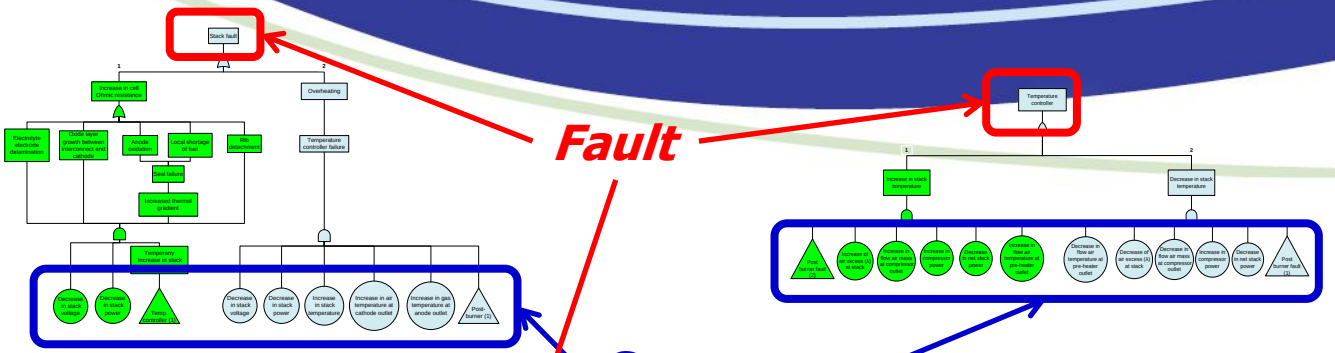
Fault tree analysis

Signature matrix

Black box model

Threshold definition
(e.g.: ± 2 σ, ± 3σ)

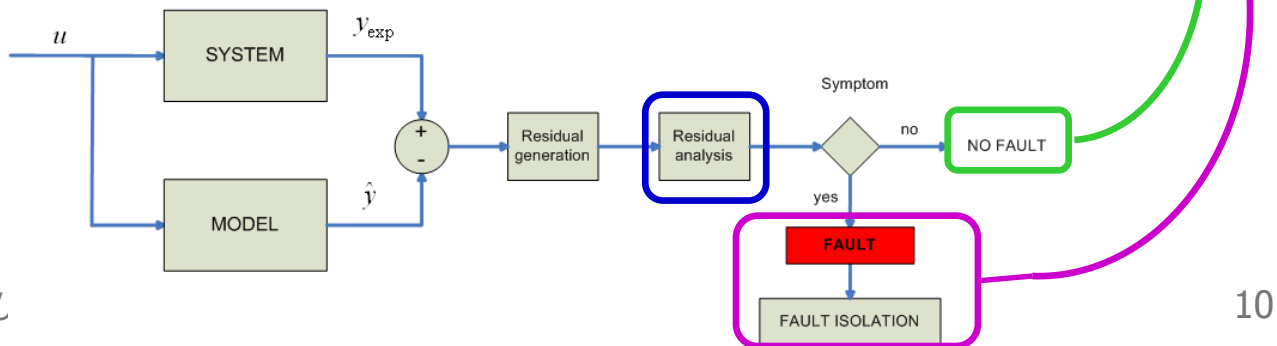
Inference



	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}	s_{11}	s_{12}	s_{13}	s_{14}	s_{15}	s_{16}	s_{17}
f_1	0	1	1	0	1	1	1	1	0	1	0	0	0	0	0	1	1
f_2	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
f_3	0	1	1	0	1	1	0	1	0	1	0	0	0	0	0	1	1
f_4	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
f_5	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
f_6	1	1	1	0	1	1	0	1	0	0	1	1	1	0	0	1	1

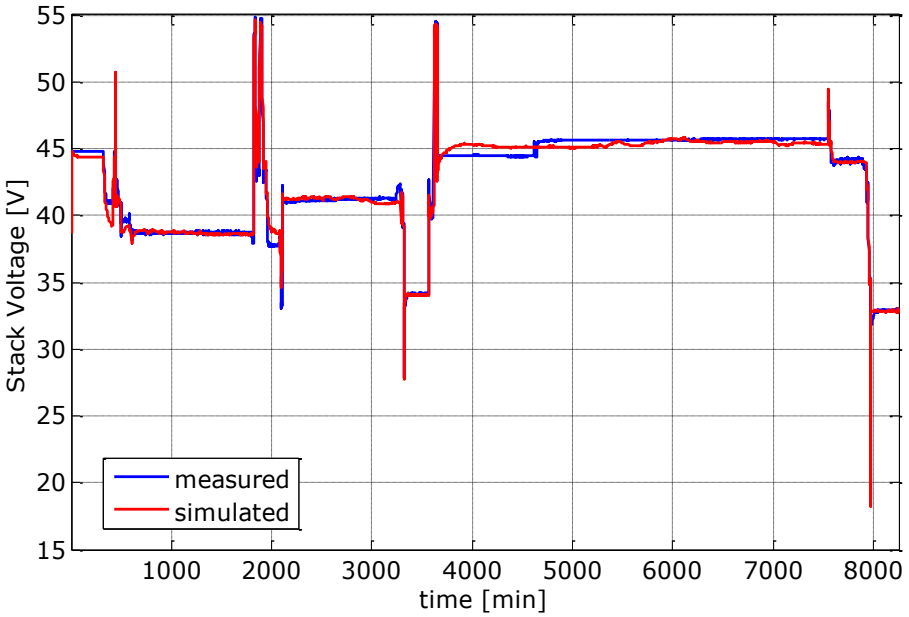
= 1

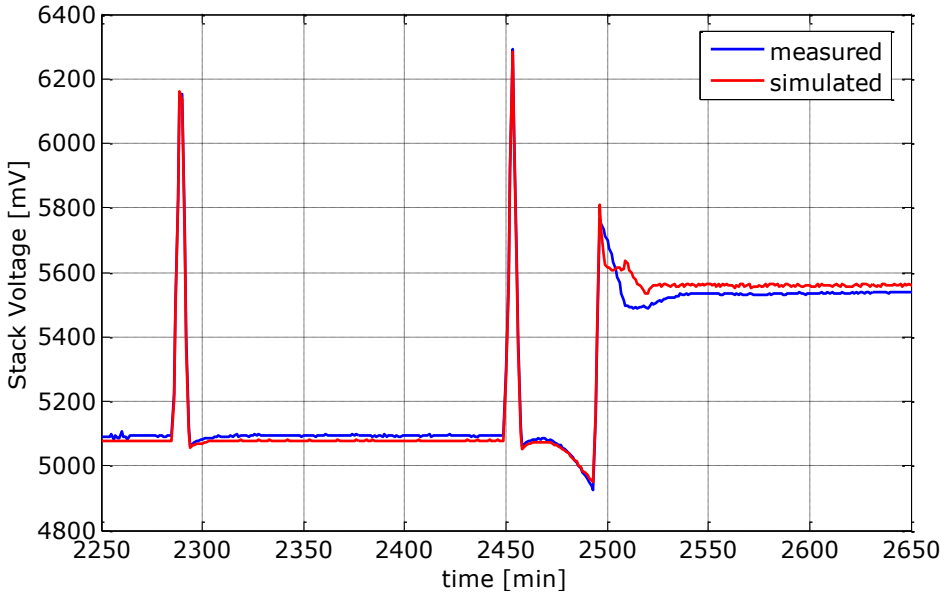
= 0



GENIUS

W.T 4.1: Black box model based algorithm performances



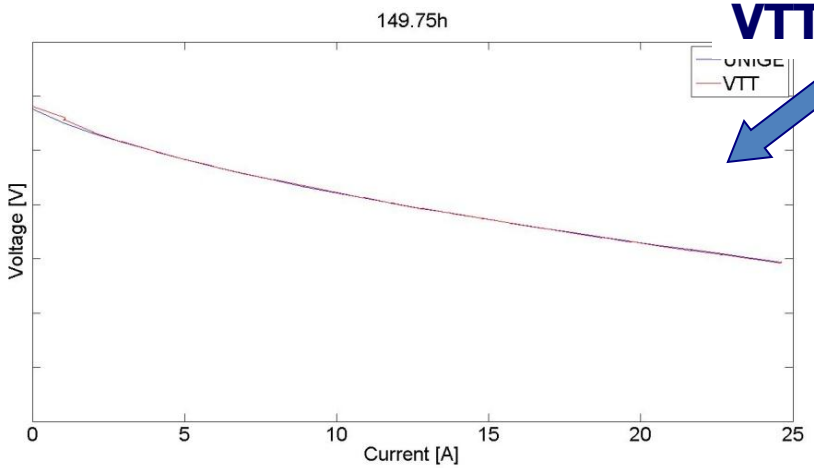


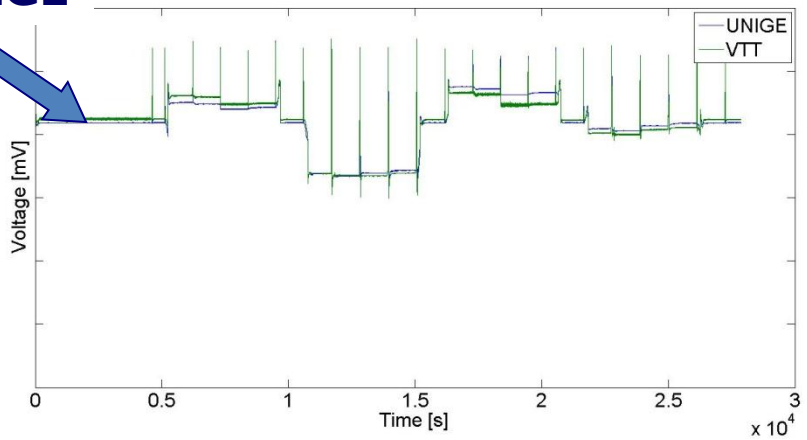
Stack supplier: TopSoE
Measures: TopSoE
Simulations: UniSA

Stack supplier: HTc
Measures: VTT
Simulations: UniSA

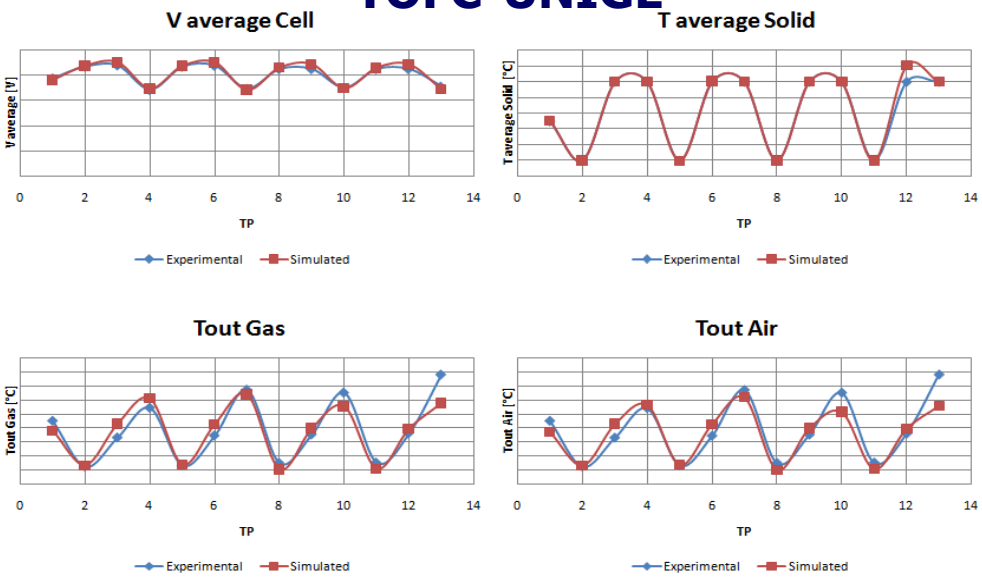
W.T 4.2: Grey box model based algorithm performances

VTT-UNIGE

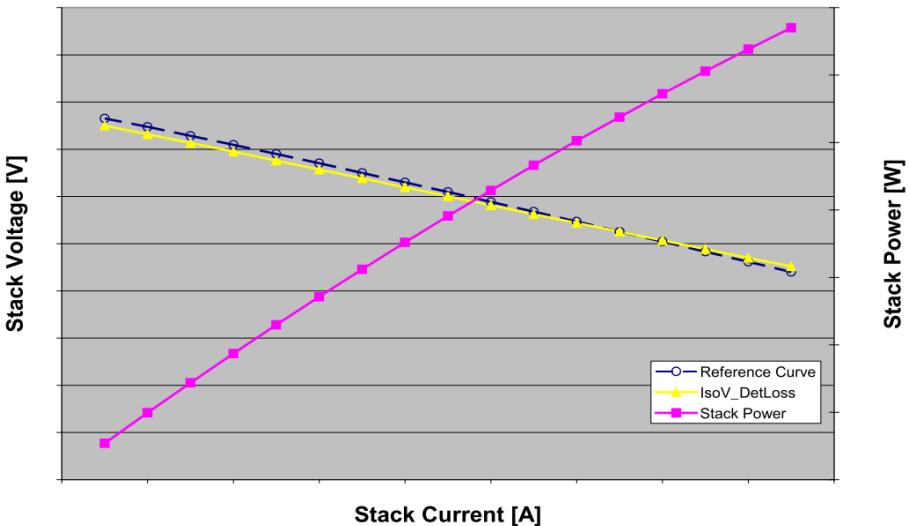




TOFC-UNIGE



EBZ-UNIGE



Stacks and systems to be tested during validation phase

WÄRTSILÄ system tested by WÄRTSILÄ

Galileo®
HEXIS's system tested by **EIFER**

EBZ system tested by EBZ

Alignment to MAIP- AA3
Stationary Power Generation & Combined Heat and Power

"The aim will be to deliver new or improved materials as well as reliable control and diagnostics tools both at a component and at system level."

The main project objective is to develop a **Generic diagnostic algorithm integrated in a standard hardware equipment**

“The aim will be to achieve the principal technical and economic specifications necessary for stationary fuel cell systems to compete with existing and future energy conversion technologies”.
"In addition, substantial effort is needed to address lifetime requirements of 40,000 hours for cell and stack, as well as competitive costs, depending on the type of application."

The developed **generic diagnostic algorithm** will allow detecting the faults and prevent failure before their occurrence, resulting in a better system reliability which will:

→improve the competitiveness of fuel cell versus other presently used µ-CHP technologies by increasing the availability ratio.

→Improve the competitiveness of fuel cell versus other technologies (e.g. Marine applications)

→**substantially increase system lifetime**.

Alignment to AIP 2008 – Topic 3.3
Operation Diagnostics and Control for Stationary Power Application

"Focused efforts are required to address lifetime requirements of 40,000 hours for cell and stack, as well as commercial target costs, depending on the type of application."
"Applied research activities are directed towards developing components and sub-systems with improved performance, durability and cost for all three technologies in order to achieve system application readiness."

The main project objective is to develop a **Generic diagnostic algorithm integrated in a standard hardware equipment** which will allow detecting the faults and prevent failure before their occurrence. This will resulting in a better system reliability which will **increase system lifetime in order to address the requirements of 40 000 hours**.

"Improved prediction and avoidance of failure mechanisms"

→ Signatures of selected failure mechanisms will be experimentally evaluated and suitable data analysis methods developed in order to **separate the effect of each failure mechanism** from normal base-line stack degradation at an early stage. This **early detection** will allow **minimizing degradation** by **optimizing system operating parameters**.

"Development of strategies for recovery of cell and stack performance"

→ One main target of the project is to provide **recommendations for recovery strategies**.

Education & Training:

2 PhD students funded at FC Lab and UniSA, who spent time at partners laboratories

Organisation of workshops:

• Common meeting with Design consortium (M13) *to determine the most probable and the most critical events for the stack operation that are observed at system level.*

•Workshop in Viterbo (M19) about degradation causes and effect.

Publications & Communications:

•1 scientific paper published in Int. J. Hydrogen Energy + 1 submitted to Fuel Cell Journal.

•3 presentations at conferences.

•Project presentation in a workshop organized by Prof. Robert Steinberger about "Systems and systems components".

Public website: https://genius.eifer.uni-karlsruhe.de/

Technology transfer and collaboration

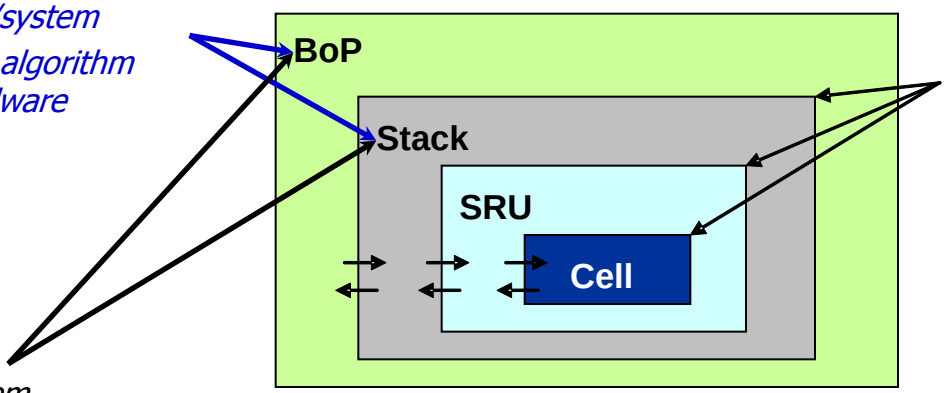
- **Collaborations**

GENIUS

Object: SOFC system

Sensor: SOFC stack/system

Outcome: diagnosis algorithm integrated with hardware



DESIGN

Object: SOFC (from SRU to stack)

Sensor: various levels

Outcome: Method and signatures as input for a diagnostic tool + recovery strategy recommandations

D-CODE

Object: PEMFC system

Sensor: Electrochemical Impedance Spectroscopy made by the DC/AC inverter

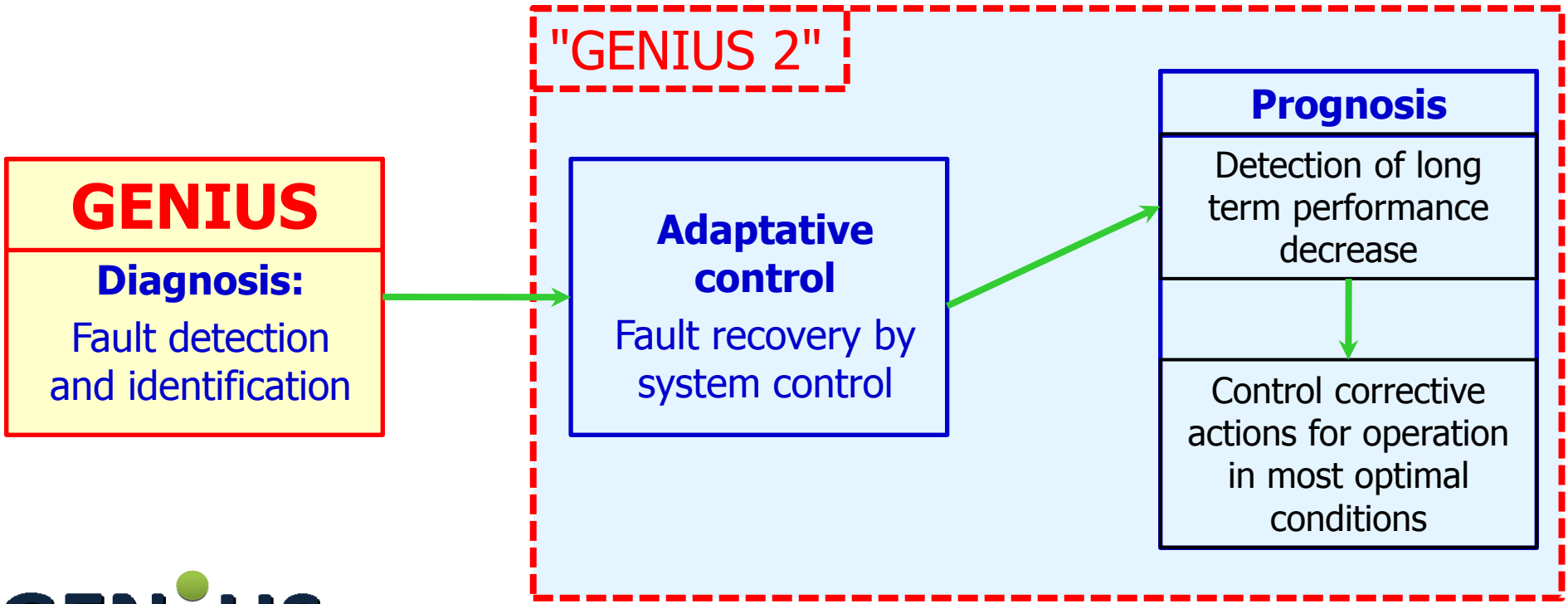
Outcome: diagnosis algorithm + Impedance measurement hardware

- **Technology Interfaces**

➡Enhanced interface between stack/system manufacturers and diagnosis algorithm developers

Genius possible future perspectives

From diagnosis to prognosis:



Generalize the scope of diagnosis applications to all FC and H_2 technologies and applications
Genius possible future perspectives

GENIUS (EU-JTI)

Diagnosis for SOFC:

Hardware: *standard PC + OPC protocol*

Algorithms: *model and knowledge based*

Applications: *µ-CHP*

D-CODE (EU-JTI)

Diagnosis for LT- and HT-PEMFC:

Hardware: *DC/AC converter*

Algorithms: *model and knowledge based*

Applications: *µ-CHP & back-up*

DIAPASON 2 (ANR-Fr)

Diagnosis for LT- PEMFC:

Hardware: *On-board modules with GMR*

Algorithms: *knowledge based*

Applications: *µ-CHP & automotive*.

Future project

Generic diagnosis for all fuel cell (SOFC, PEMFC, MCFC) and electrolysis technologies :

Hardware: *new sensors integrated in control loop, system components.*

Algorithms: *model and knowledge based*

Applications: *µ-CHP, automotive, H_2 production by electrolysis, stationary,… (⇔ cross cutting issues ?)*