



Centre Français Fiabilité

HIGH RELIABILITY ENERGY Center of Competence

Bridging Emerging Technologies to Harsh Environment Operation !



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GENERAL CONTEXT & CONTRIBUTION TO ELECTRIFICATION CHALLENGES

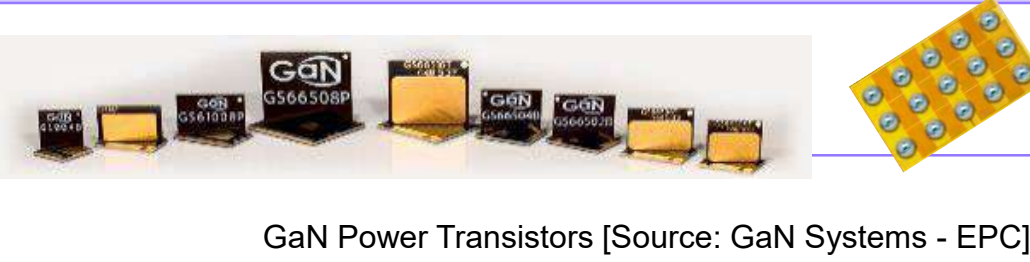
Enable Increased Electrification of Systems by Focusing on **DEPENDABILITY*** of Embedded Electronics

* System *ability to avoid* service failures that are more frequent and more severe than is acceptable. The concept of *dependance* leads to that of *trust*. In French: » Sureté de fonctionnement » est souvent appelée la « science des défaillances et des pannes »

[Source: A. Aitken, J.C. Laprie et al., IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING, VOL. 1, NO. 1]

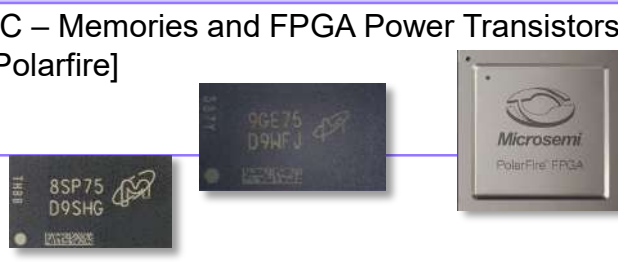
❖ **MASSIVE INTRODUCTION** of **Commercially Off-The Shelf (COTS)** components!

❖ **DENSIFICATION** (weight/volume -effectiveness) of **DIGITAL** and **POWER** electronics functions (e.g. Mechatronics)!



SERVICE
FUNCTION
SYSTEM
EQUIPMENT
COMPONENT
MATERIAL

Reliability = Probability that a



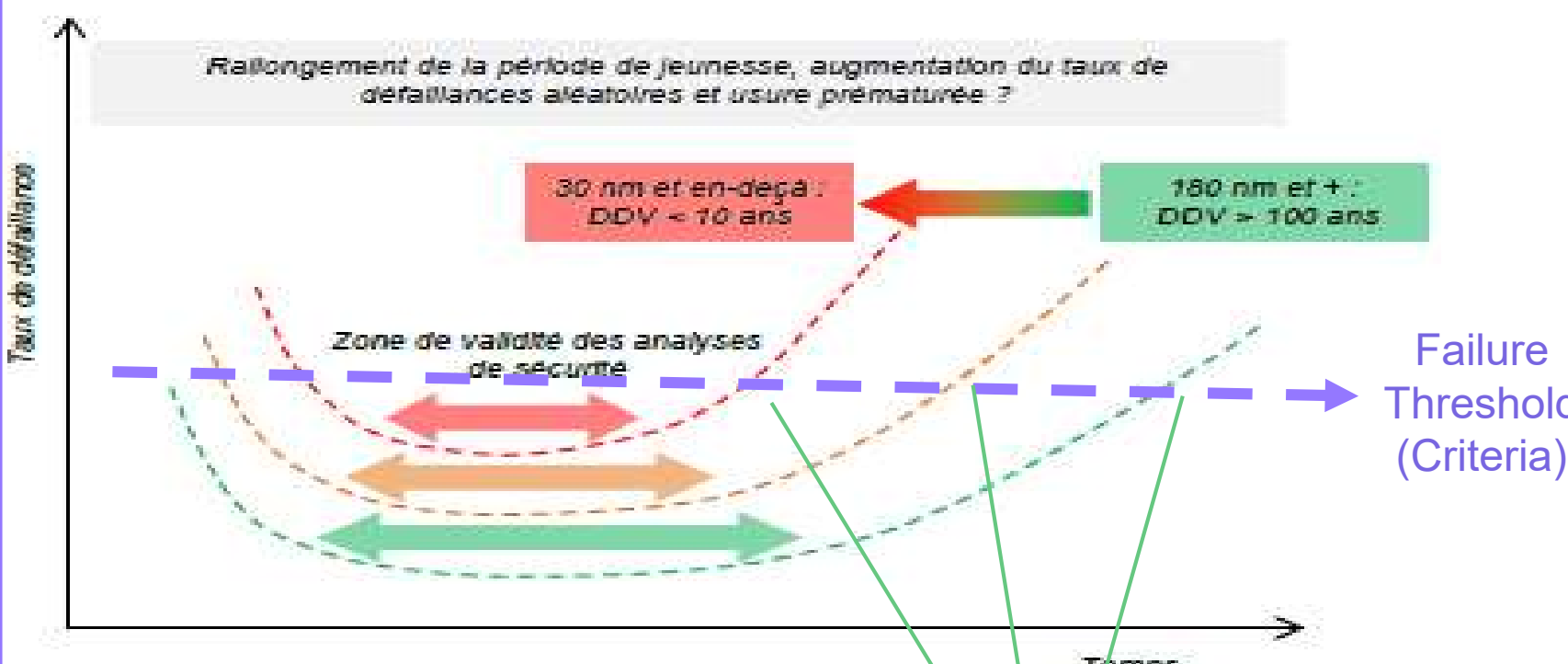
SERVICE
FUNCTION
SYSTEM
EQUIPMENT
COMPONENT
MATERIAL

Works properly (under given specs) AND for given working conditions (self-induced and environment)

ENABLE

**SAFETY
AVAILABILITY
&
GREENER Deployment**

**In Severe Operating
Conditions !!!**



Reliability = **ROBUSTNESS** + **DURABILITY**

[FIT]

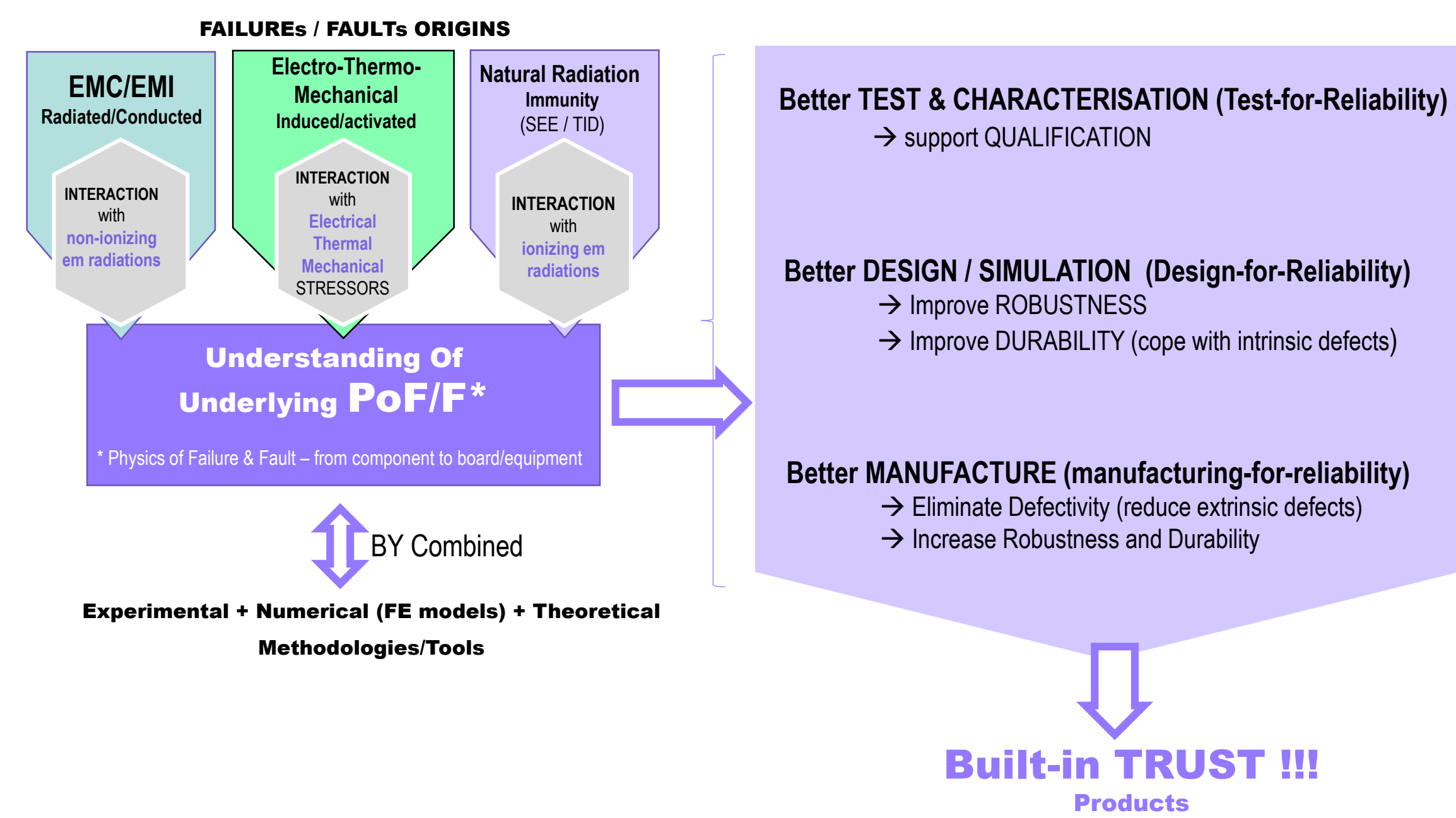
[Year or Hours]

Capability to withstand (Insensitivity to) instantaneous over-stress

Capability to withstand (Insensitivity to) aging

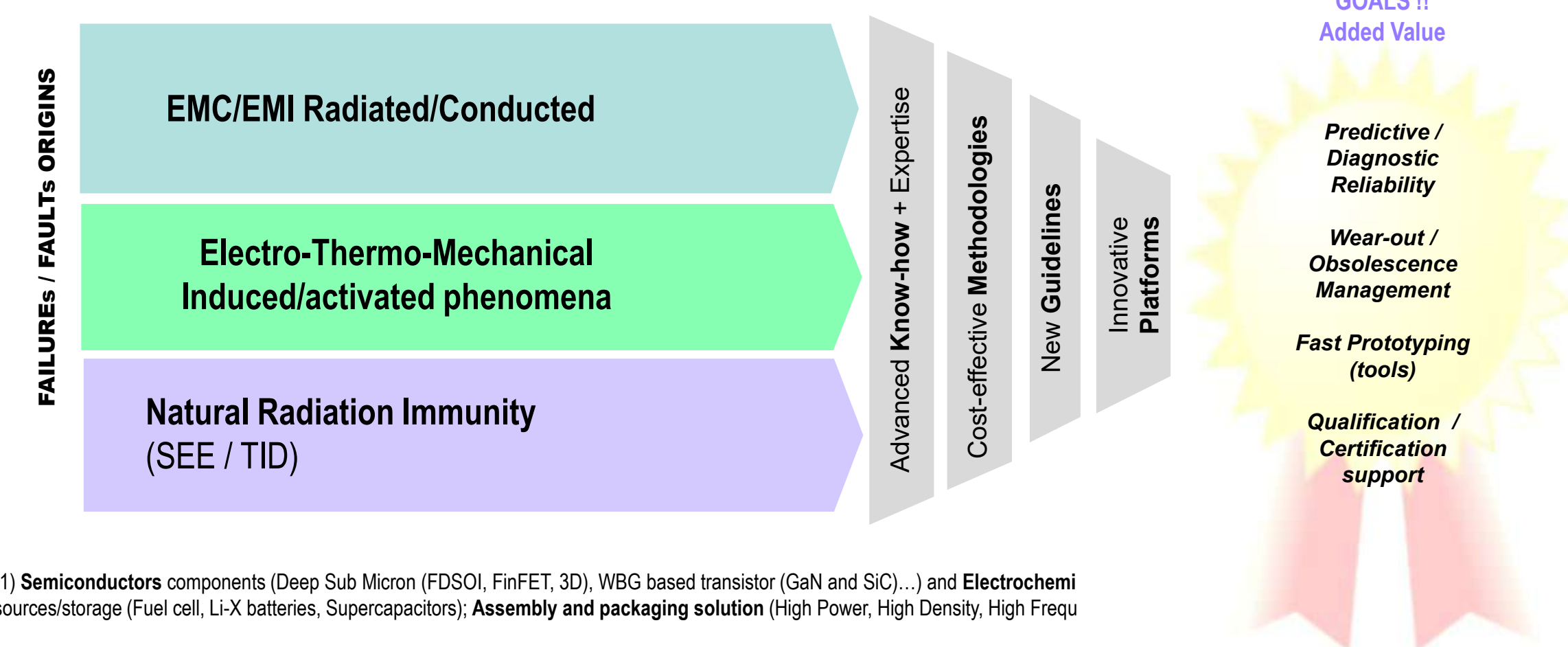
IMPLEMENTATION STRATEGY

Rational



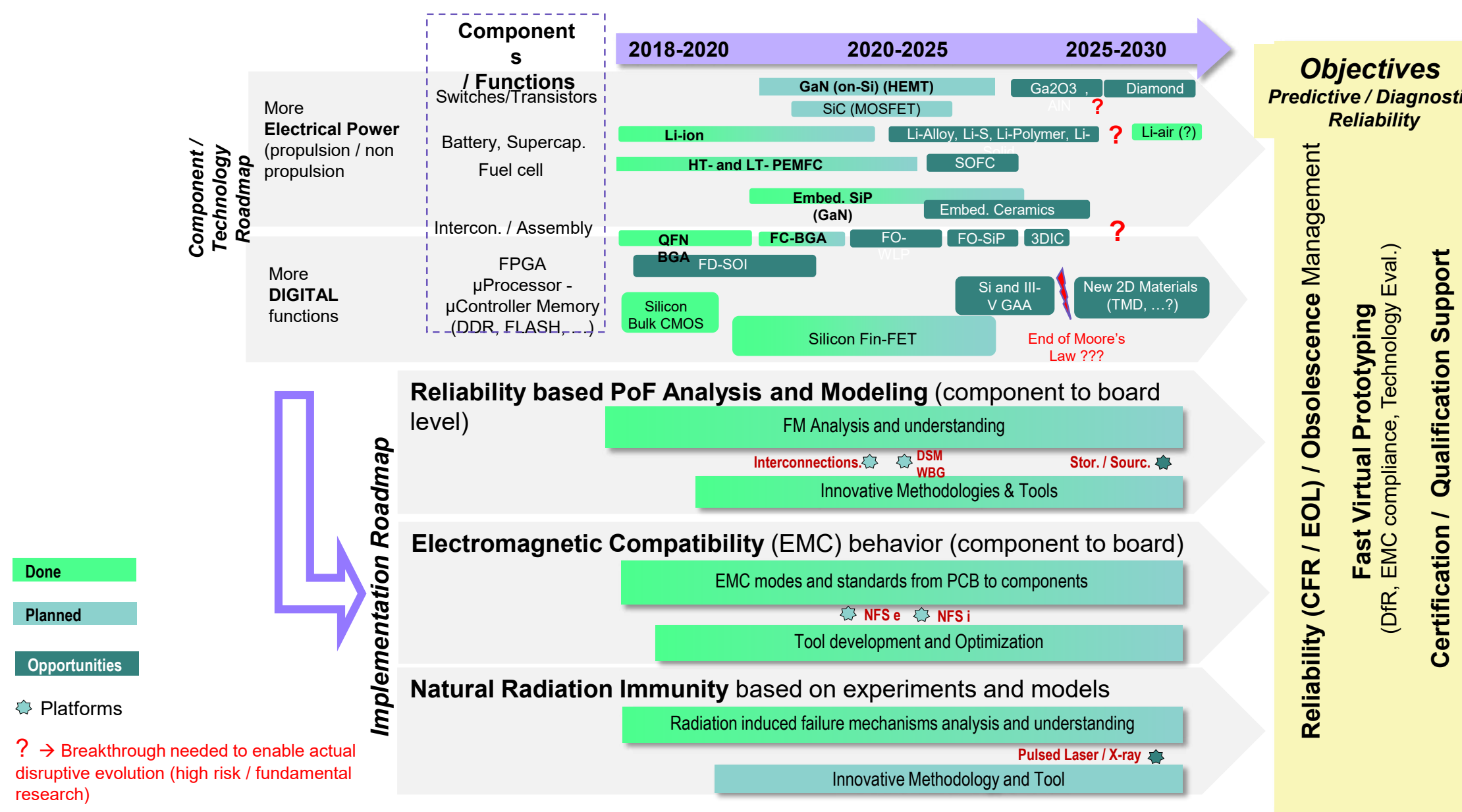
Proposed Added Value

Bridging (COTS⁽¹⁾ based on) emerging technologies to harsh environment operation

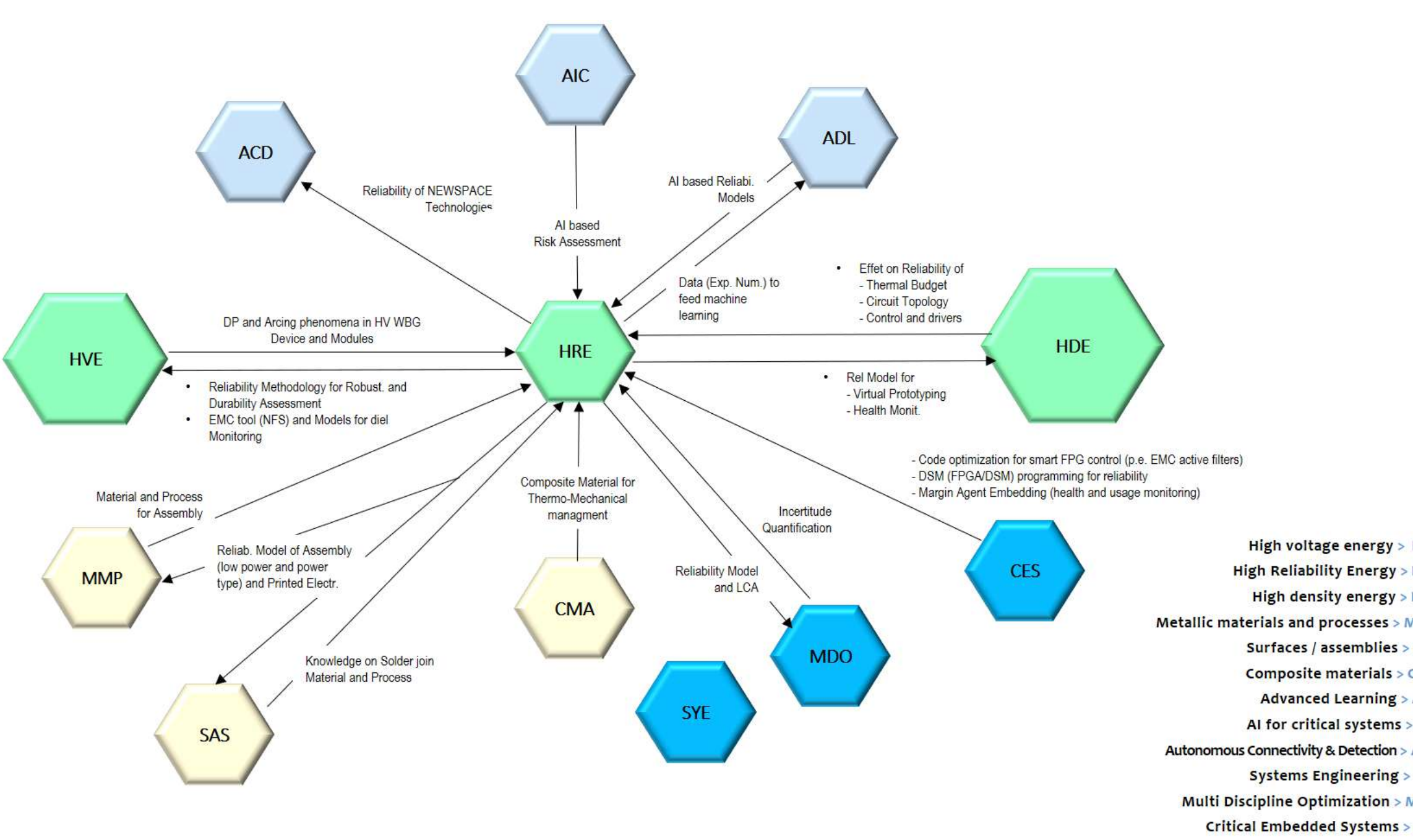


(1) Semiconductors components (Deep Sub Micron (FDSOI, FinFET, 3D), WBG based transistor (GaN and SiC)...) and Electrochemi sources/storage (Fuel cell, Li-X batteries, Supercapacitors); Assembly and packaging solution (High Power, High Density, High Freq)

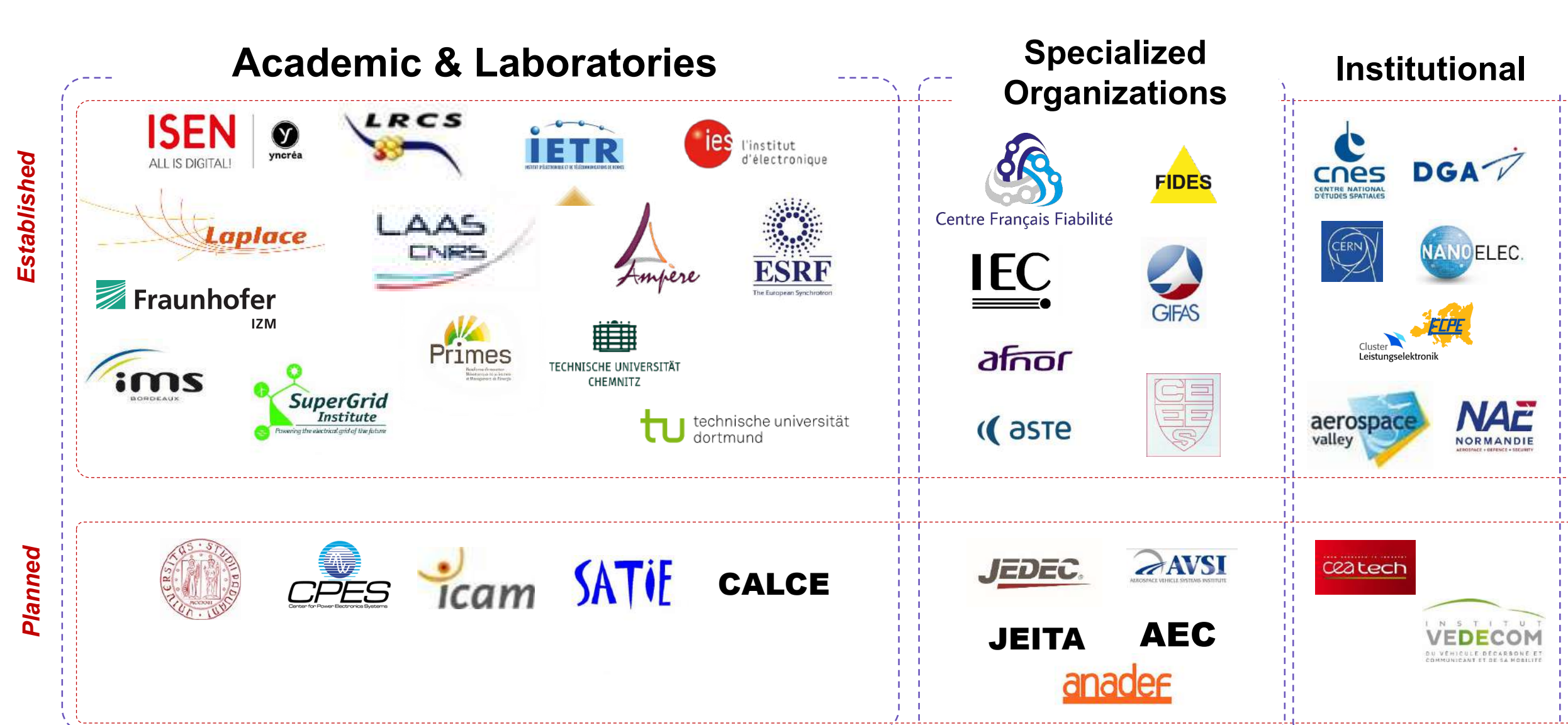
Roadmap



IRT Internal Cross-fertilisation



PROFESSIONAL ECOSYSTEM



TEAM :



Contact:



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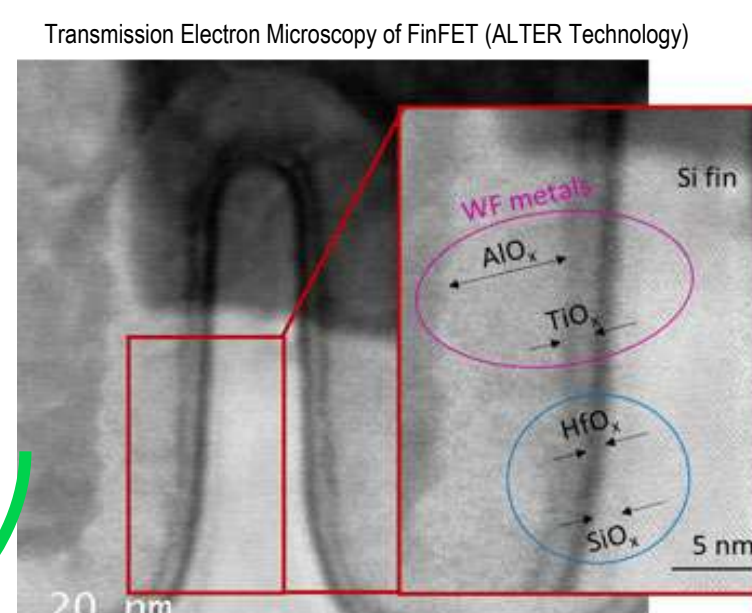
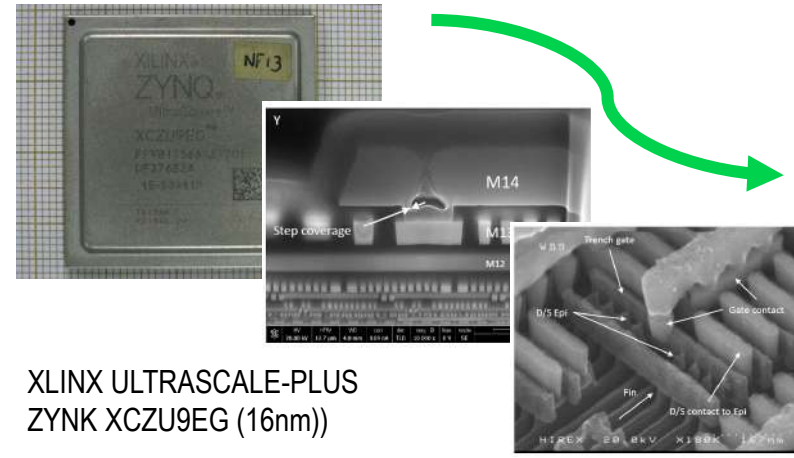
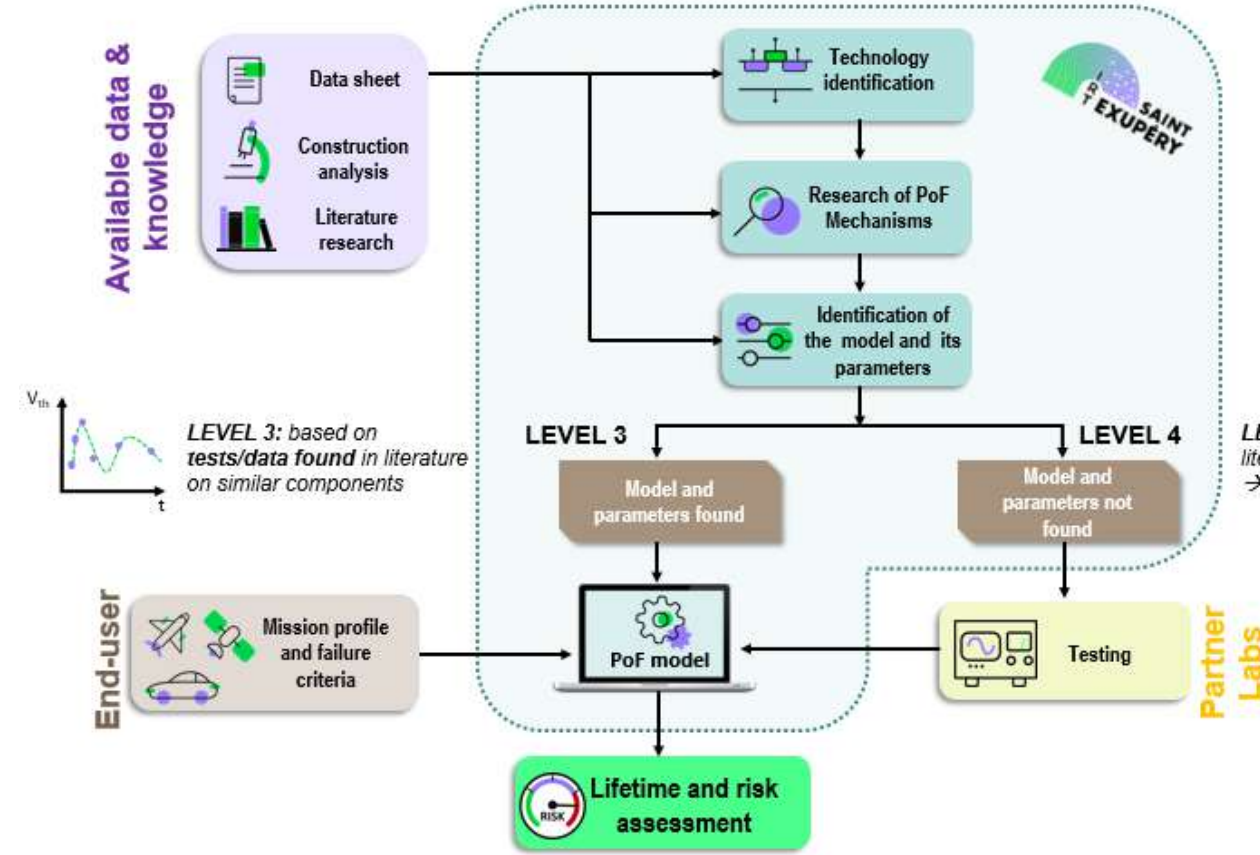
Bridging Emerging Technologies to Harsh Environment Operation !



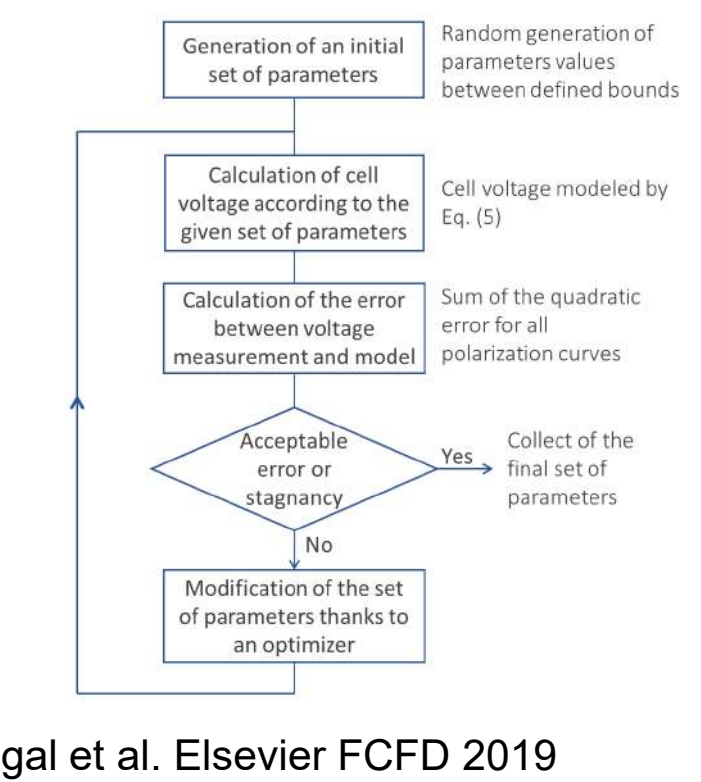
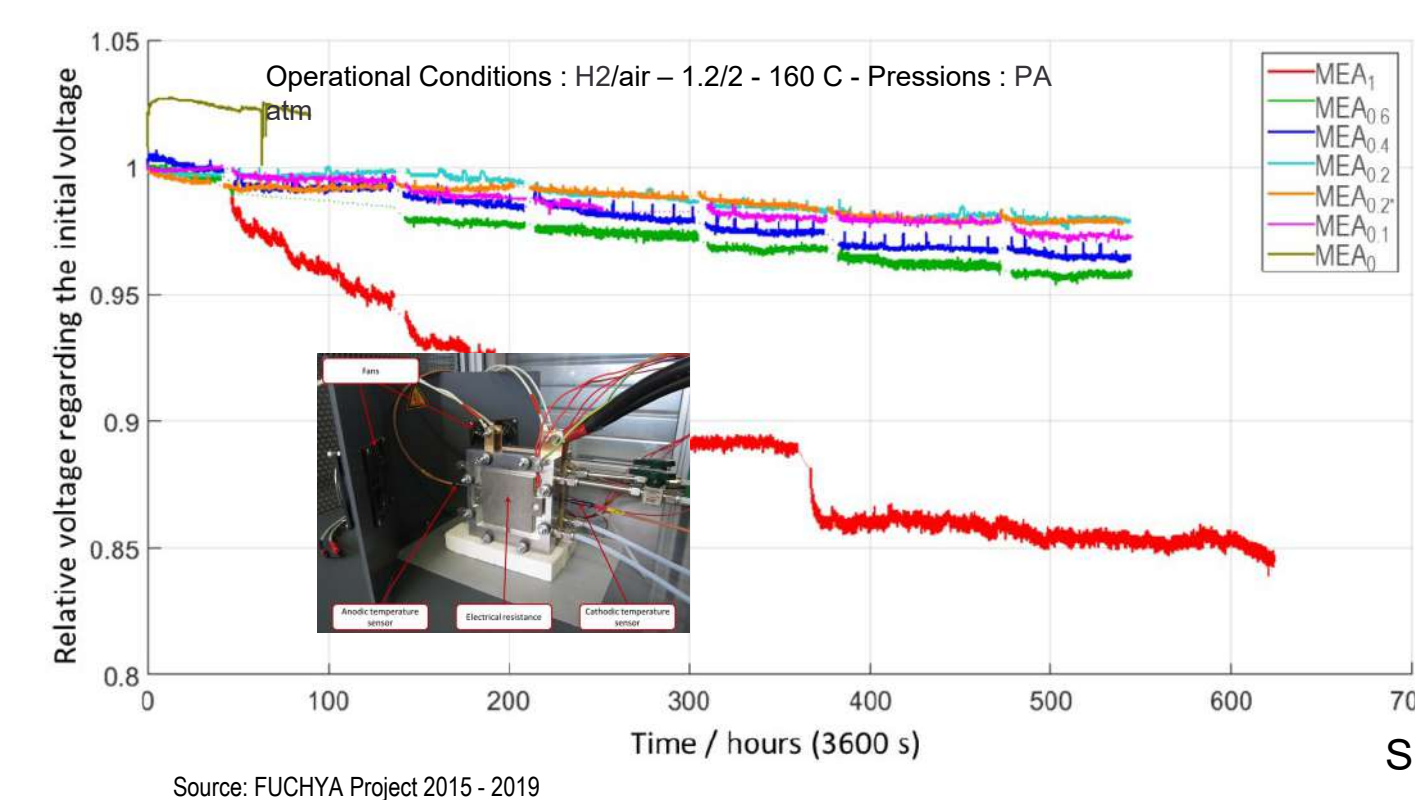
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SOME INDUSTRIAL TRANSFERT AT A GLANCE

Failure Risk Assessment Methodology (FRAME)



Ageing Test and Modeling on PEMFC Temperature (HT) Membrane Electrode Assemblies (MEAs)



Qualification Protocols

SIC MOSFET

Revealed effects

- Charge trapping (BTI) → parameter drift

Expected results

- Failure mode and localization
- Acceleration factor
- Initial characterization / selection of tested devices
- Main relevant parameters on Vth / Rdson drift
- Influence of variability of device characteristics
- Test procedure

Stressors / Levels

Stressors	Levels
Gate voltage	Min, Max
Drain voltage	Min, Max
Gate current	Min, Max
Drain current	Min, Max
Temperature	Min, Max
Time	Min, Max

Initial characterization

- Selection of device (BV)
- ALTER test program
- Vth1
- Ig1
- CG1, Cgs and Cgd1

Intermediate measurements / Readouts

- Readouts - ALTER test program @ Room temperature

After stress characterization

- Vth2 with different waiting times
- Ig2
- CG2, Cgs and Cgd2
- CV1 hysteresis

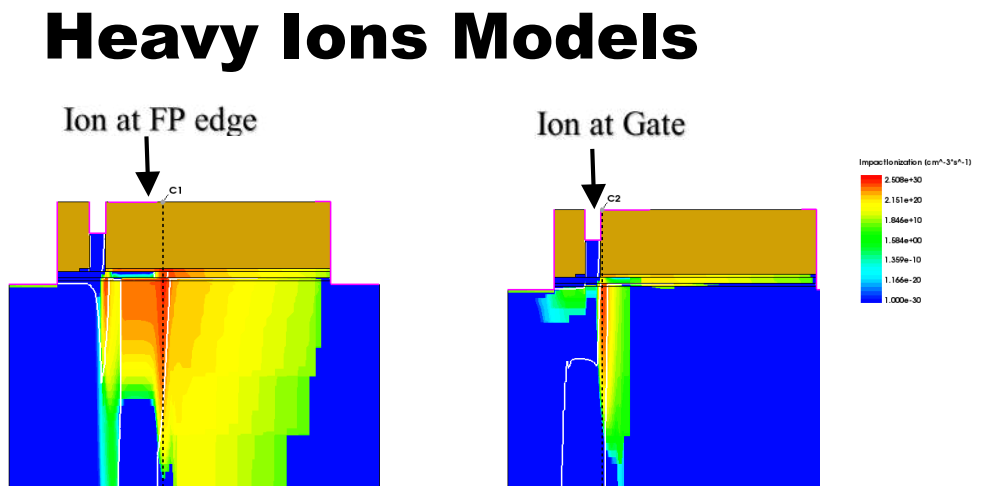
Open points

- Interaction effect on Vth recovery
- Methodology to measure Vth
- Drift Vth saturation or not (New traces or not?)

ALTER test program

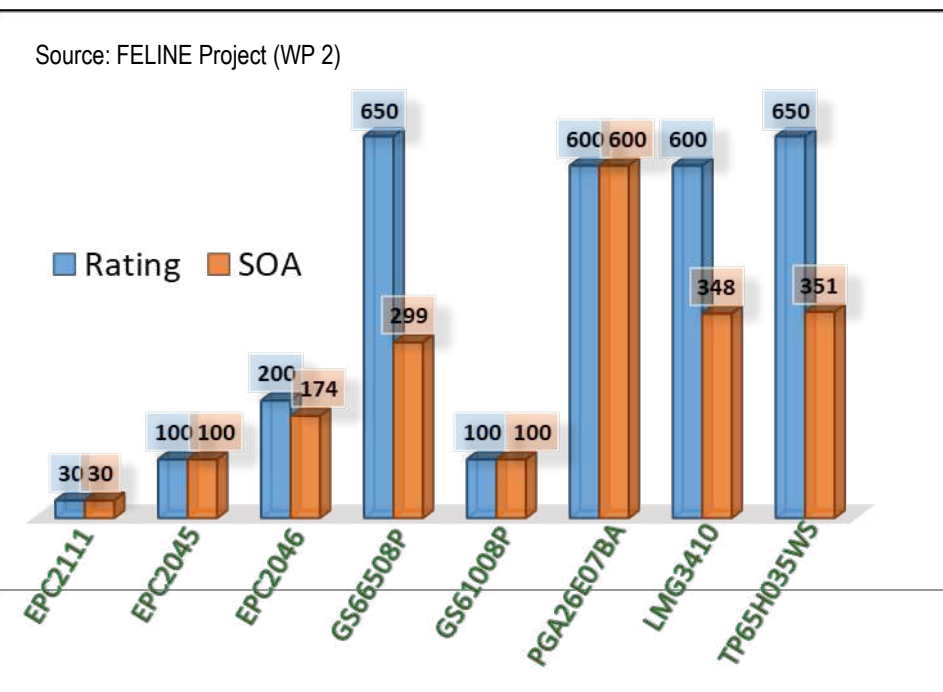
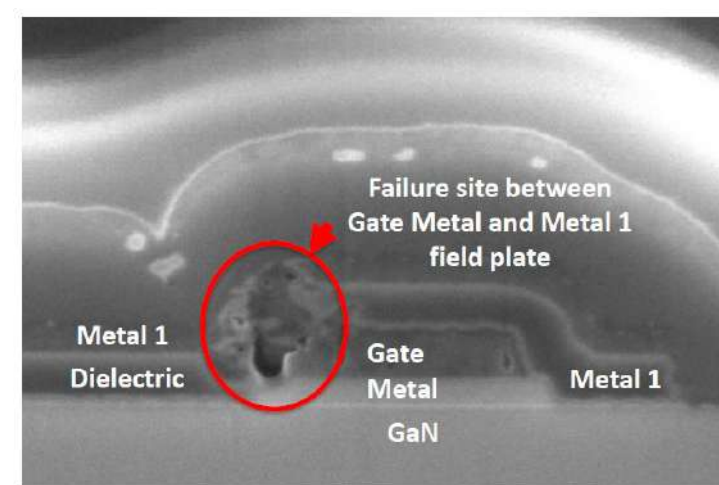
Source: SICRET Project 2020 - 2023

TCAD Modeling of SEE Heavy Ions Models



M. Zerarka et al. IEEE Transaction on Nuclear Science 2018

Source: FELINE Project (WP 2)



Source: FELINE Project (WP 2)

SOA definition For WBG (SiC and GaN) technologies

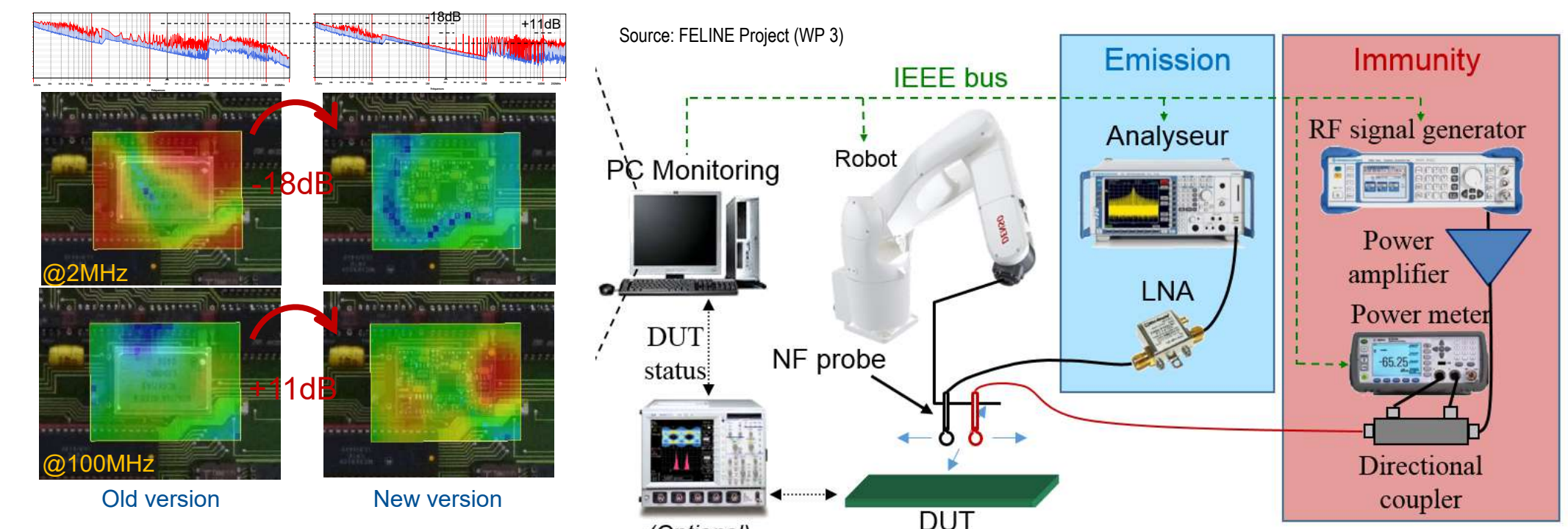
Electro- Thermo- Mechanical Phenomena

Natural Radiation Immunity (SEE / TID)

EMC/EMI Radiated & Conducted

Obsolescence Management

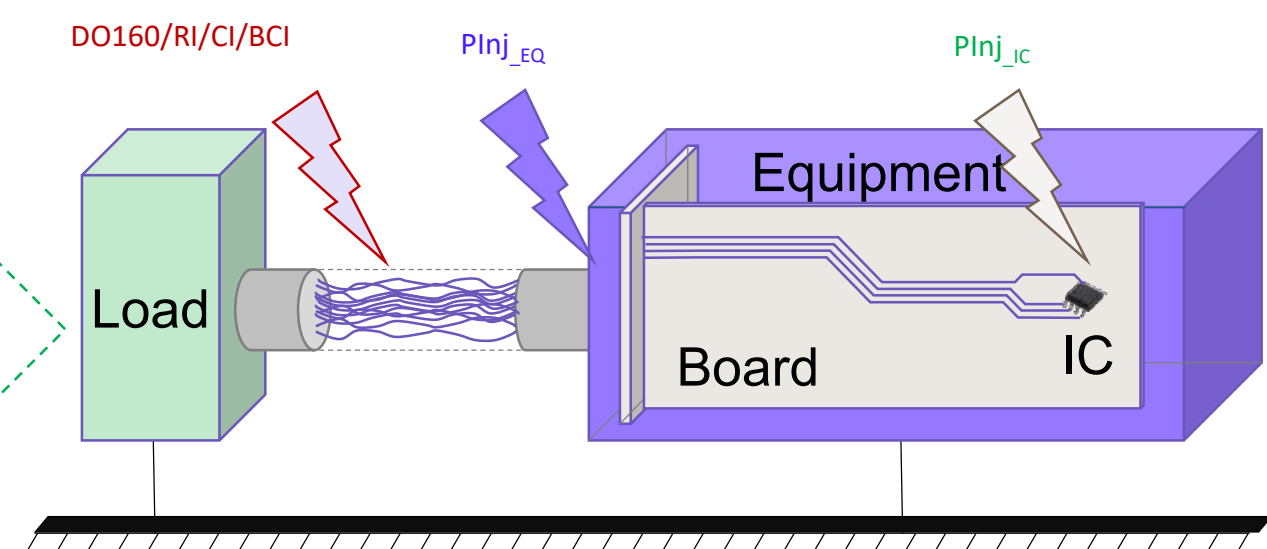
Obsolescence investigation by NFSe measurement



S. Serpaud et al. IEEE Transaction on EMC 2020

Harness Disturbance coupling Modeling Tools (SCALP)

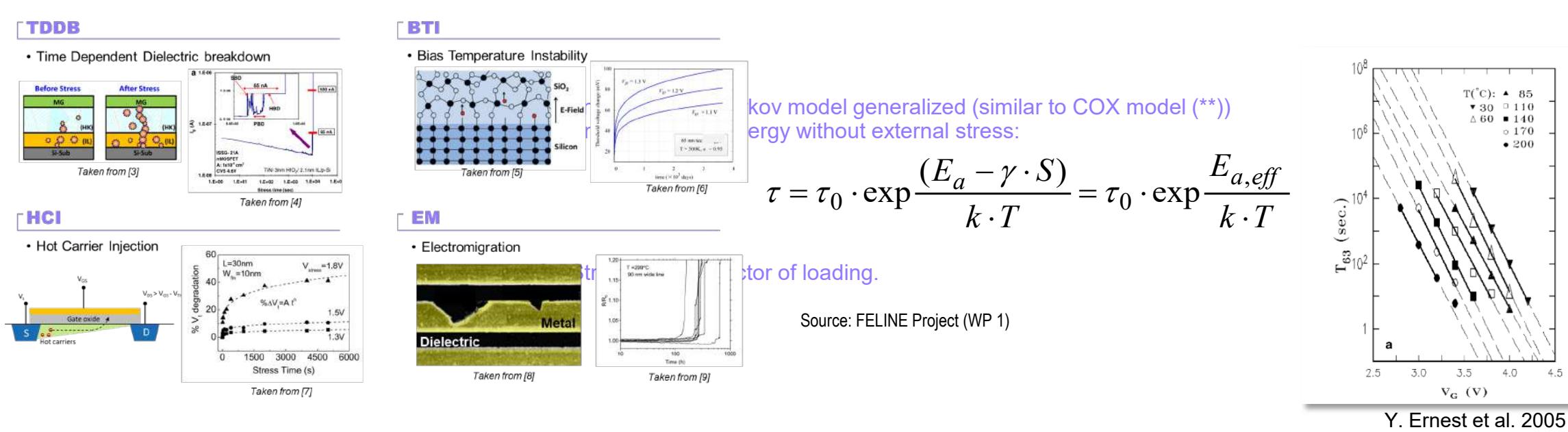
- Investigation modelling/simulation analytic (1D, 2D) tools
- Harness disturbance coupling modelling : SCALP (Scilab)
- Indirect N-Ports measurement de-embedding tools
- Near Field Propagation : NFSe (PWS approach)
- PCB modelling : MESSA (Python)
- Uncertainty management : Bayesian calibration (Python)
- GEMSEO : Multidisciplinary Design Optimization (open software)



EXAMPLE OF SCIENTIFIC ACHIEVEMENTS

MAIN INDICATORS: 13 Thesis / 5 PostDoc / >50 Peer Review Papers / 3 Conference Prizes

Multimechanisms Multistressor Reliability Models



kov model generalized (similar to COX model (**))
ergy without external stress:

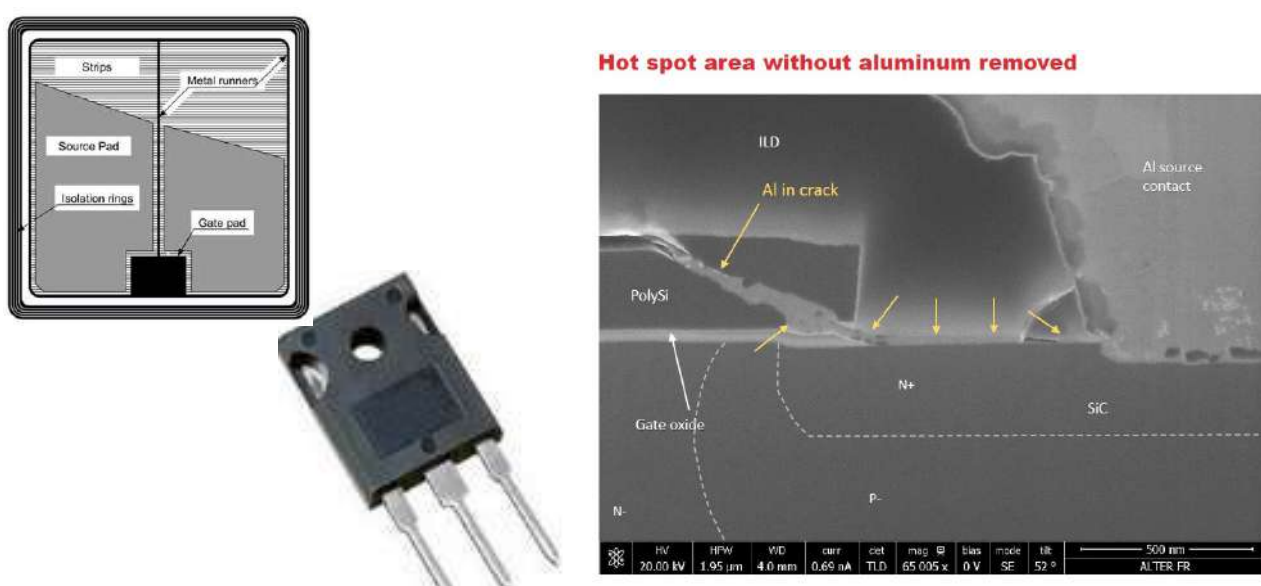
$$\tau = \tau_0 \cdot \exp\left(\frac{E_a - \gamma \cdot S}{k \cdot T}\right) = \tau_0 \cdot \exp\left(\frac{E_{a,eff}}{k \cdot T}\right)$$

for of loading.

Source: FELINE Project (WP 1)

Y. Ernest et al. 2005

Robustness investigation Know-how Short circuit in SIC MOSFET



Y. Barazi et al. - Energy 2021

The High-power stress apply on the component makes a thermal-mechanical stress on ILD leading to aluminum propagation in the crack inducing electrical leakage

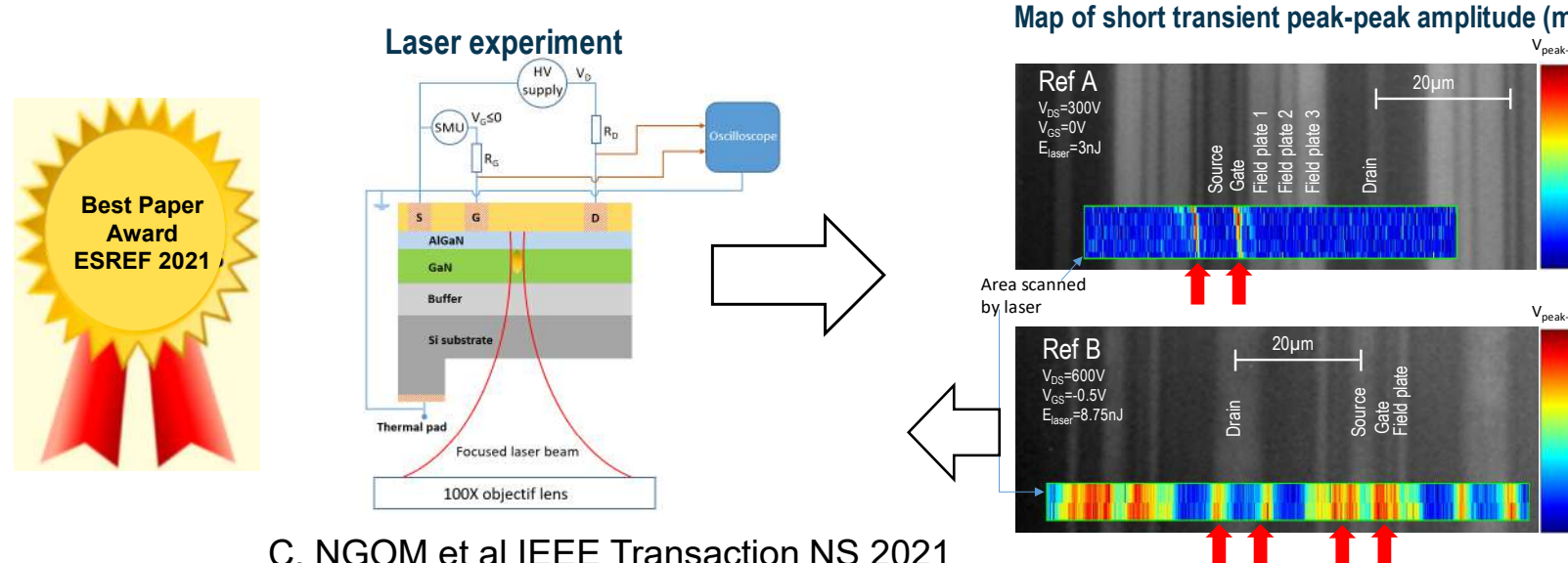
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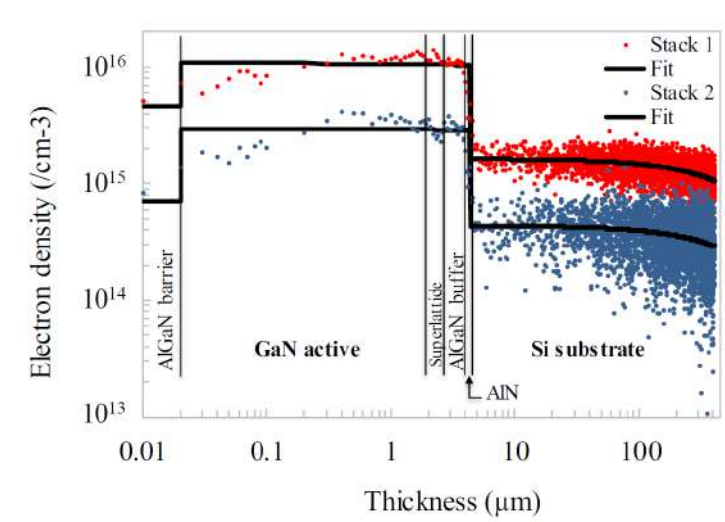
EMC/EMI Radiated & Conducted

Pulsed X-ray based methodologies

Modelling the Influence of Package in Focused X-ray Testing of Power GaN COTS



C. NGOM et al IEEE Transaction NS 2021



Electron density (cm-3)

Thickness (µm)

Stack 1

Stack 2

Stack 3

Stack 4

Stack 5

Stack 6

Stack 7

Stack 8

Stack 9

Stack 10

Stack 11

Stack 12

Stack 13

Stack 14

Stack 15

Stack 16

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