SIMPOSIUM

Interoperable NDE simulation tools

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SIMPOSIUM : Simulation Platform for Non Destructive Evaluation of structures and materials

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TERRIFIC Workshop

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SEVENTH FRAMEWORK PROGRAMME

Outlines

- **Context of the project :**
  - Non destructive testing
  - Materials characterization
- **Objectives of the project**
  - Simulation platform with NDT / MC
  - Connexion with Design and mechanical software
- **Main achievements**
  - Work Plan and summary of WPs
  - Dissemination
- **Perspectives: connexion to other topics**

Context : Materials Characterization

Objective : To determine material properties of a structure to ensure that they fit its future use

Example from Simposium applications cases driven by user:

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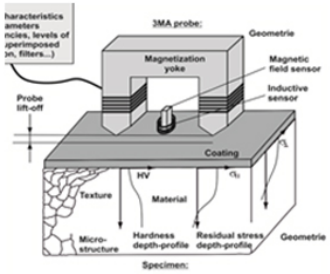
- **Objective:** Determination of mechanical properties (Rm and Rp0,2) after heat treatment with high accuracy thanks to micromagnetic measurement (non destructive evaluation method)



3MA : Multi-parameter Micro magnetic Microstructure stress Analyser.

This technology is based on the idea that there is a relation between the mechanical and the magnetic properties of a product.

- **Target:** Shafts for power generation machines

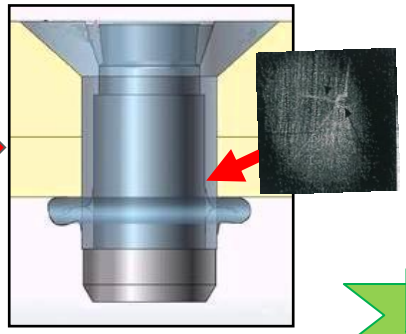
Case #5

Context: Non Destructive Testing

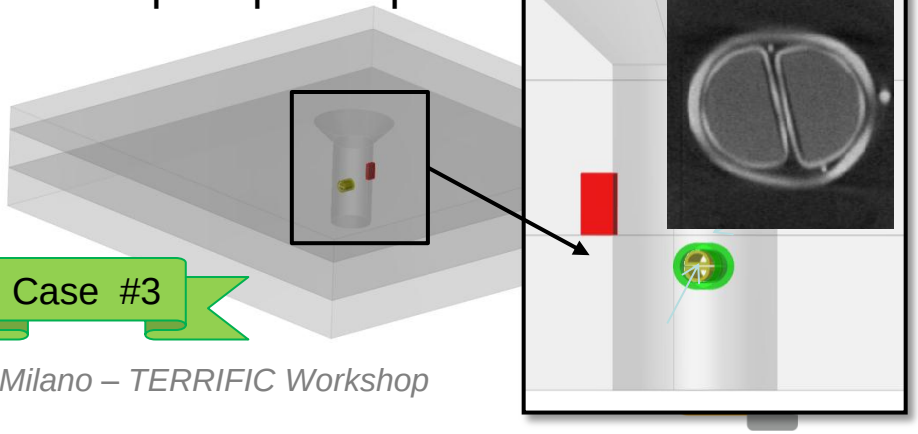
Objective: Detect and characterize flaws in structures (at manufacturing or during maintenance stages) to ensure safe use (nuclear, energy, transports)

A consequence of non detected crack: *Aloha Airlines, Flight 243, 1988 (Boeing 737)*

Origin: cracks initiated at a riveted location, propagation through the fuselage



• Complete configuration simulation : complex part + probe



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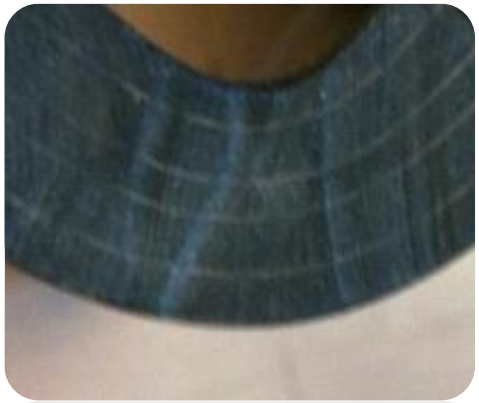
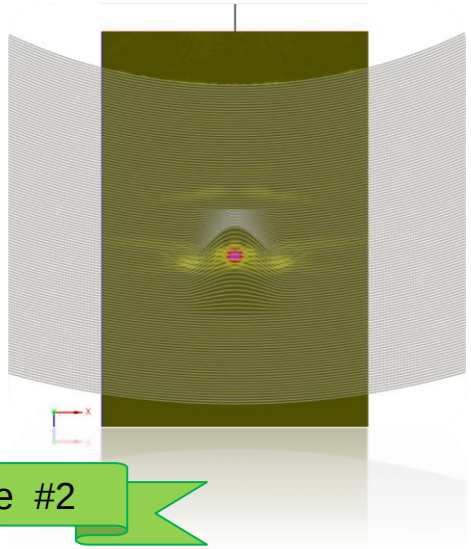
Which NDT and MC techniques?

- **<u>Ultrasonic</u>** and **<u>electromagnetic</u>** methods are widely used in both NDT and MC.
- Both methods lead to « indirect » knowledge of material properties and flaw characteristics. Understanding this effects is crucial for optimizing processes.
- Modeling of these physical interrelations is a very challenging task, conducted by many academics partners in Europe.





•Ultrasonic inspection of composite (aircraft part)

Case #2

•electromagnetic inspection of steels at caster exit (steel manufacturing)

Case #1

•Simulation shall help and reduce – not replace – costly experimental campaigns.

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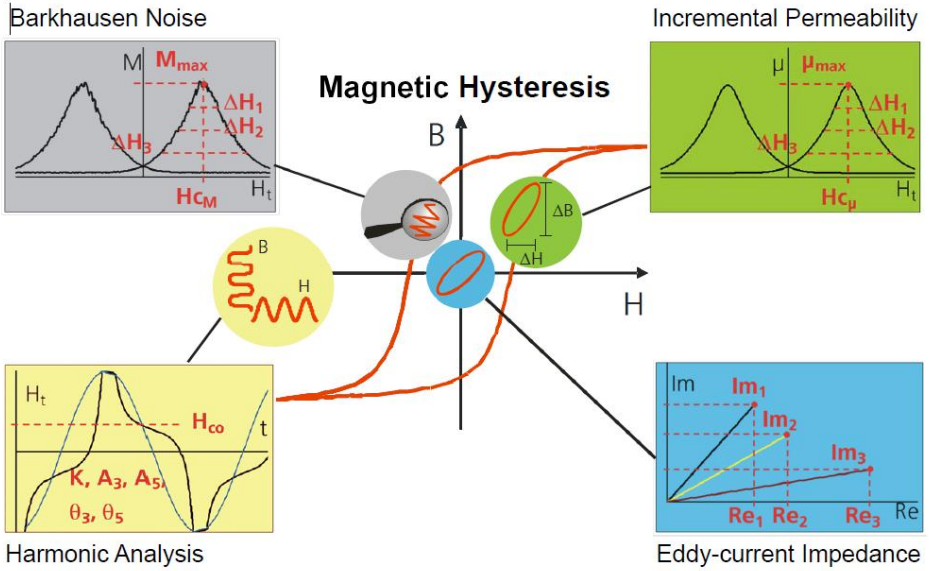
Which NDT and MC techniques ?

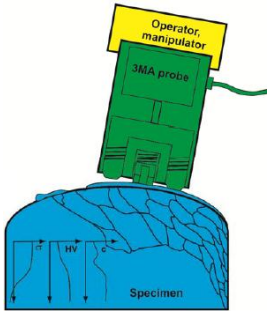
- **<u>3MA</u> technique (<u>M</u>icro <u>M</u>agnetic <u>M</u>aterial <u>A</u>nalysis)**: This technique, developed by IZFP, allows to **determine material properties from magnetic measurement** thanks to a transfer function obtained through the collection of various ET quantities associated with destructive, mechanical tests, over a subset of the samples to be characterized.

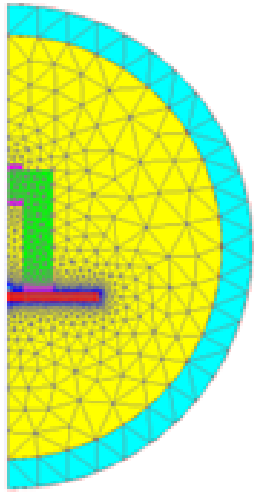
• 4 ET techniques: Barkausen noise, Incremental Permeability, Harmonic Analysis, Eddy Currents

• 1 Probe: 1 magnetic yoke(+coil) + 1 inductor (bobin coil) + 1 magnetic receiver + different settings/combination of these elements



Probe Head





FEM modeling

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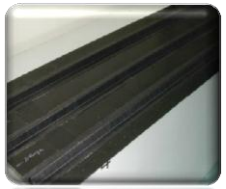
Objectives of the project (1/2)

NDT/MC in the Manufacturing (and maintenance) process

Objective 1

Developing simulation tools for efficient prediction of NDT/MC performances

→ Optimization of the manufacturing process

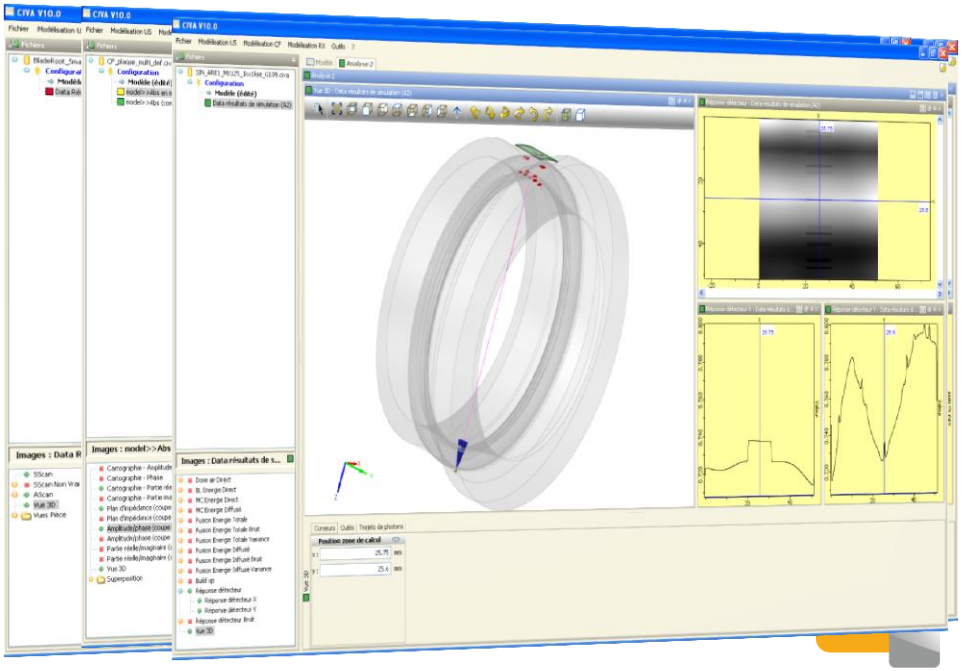


+…

11 application cases

- ***provided by end-users***
- ***to be simulated…***

Integration and/or connexion with the CIVA NDT platform (**UT,ET**,RT)



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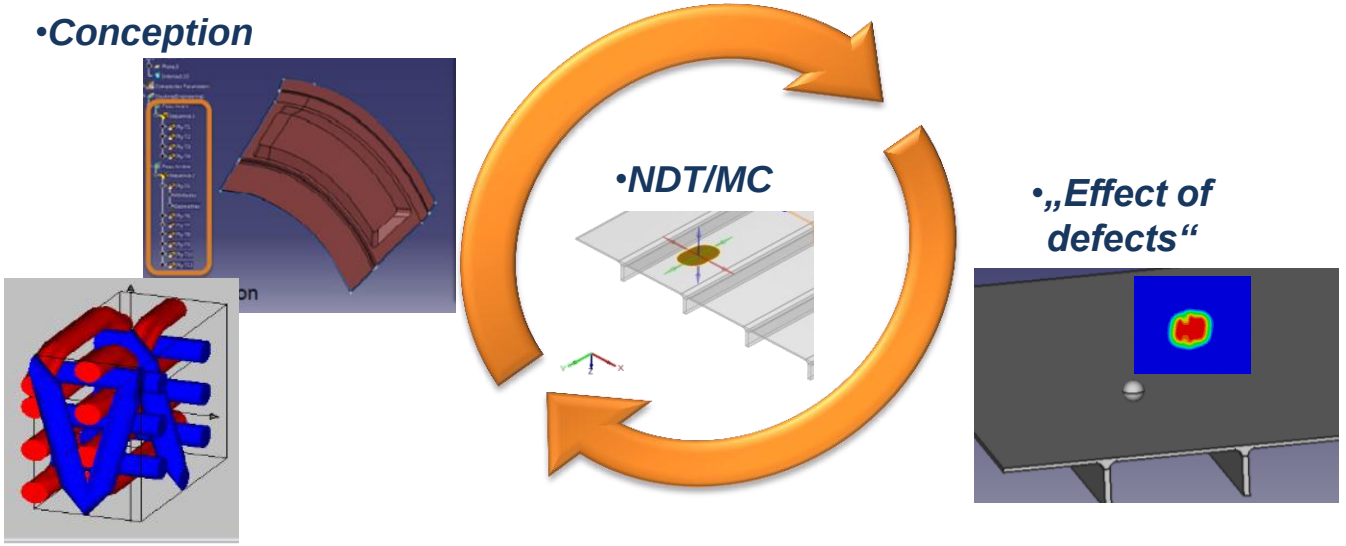
Objectives of the project (2/2)

NDT/MC in the Life Cycle of the product

Objective 2

- Develop bridges/protocols between conception & design / NDT-MC / Mechanics

→ Prediction of the “effect of defects” to the mechanical behaviour of the structure (ultimately : prediction of the remaining useful life of structures)



Feasibility studies over composites (aircrafts) applications

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Partnership

•***Industrial users***

EADS saarschmiede Freiformschmiede serco SKF Das Auto. ArcelorMittal

- **Definition of application cases**
- **Experimental tests**
- **Input data for simulation**
- **Validation of codes**

•***RTOs, Universities***

KATHOLIEKE UNIVERSITEIT LEUVEN Fraunhofer IZFP cea INRIA Imperial College London

- **Development of UT/ET simulation codes**
- **Integration/plug-in/ Connexion to CIVA**
- **Simulation of application cases**

•***SMEs***

EXTENDE CIVA

- **Valorisation**
- **Dissemination (with all)**

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Work plan and partners' roles

WP1 : Specifications
T1.1 Selection of the application cases
T1.2, Mock-ups, specimens, equipment
T1.3. Materials and defect characterization

WP2 : Interoperability of the NDE platform
T2.1 Forward compatibility
T2.2 Backward compatibility
T2.3 Software engineering for platform integration

WP3 : Simulation of UT NDE methods
T3.1 Numerical tools dedicated to UT NDE
T3.2 Simulation of UT scattering and attenuation
T3.3 Simulation of UT signals from defects
T3.4. Integration of UT tools in the NDE platform

WP4 : Simulation of ET NDE methods
T4.1 Numerical tools dedicated to ET NDE
T4.2 Simulation of μ-magnetic characterization method
T4.3 Simulation of ET signals from defects
T4.4 Integration of ET tools in the NDE platform

WP5 : Validation and applications
T5.1 Tests and validation
T5.2 Applications and evaluation

WP7 : Management and coordination

WP6: Exploitation and dissemination

WP1: Specification and preparation

Lead : ArcelorMittal

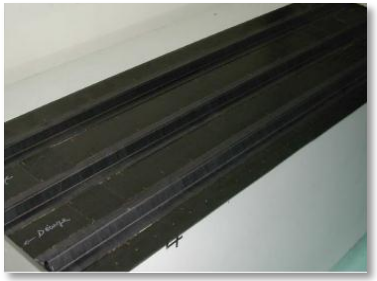
Involved partners : All (mostly : industrial users)

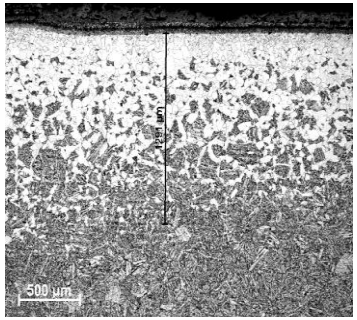
Tasks:

T1.1 : Selection of the application case

T1.2 : Mock-ups, specimen and equipment

T1.3 : Materials and defect characterization



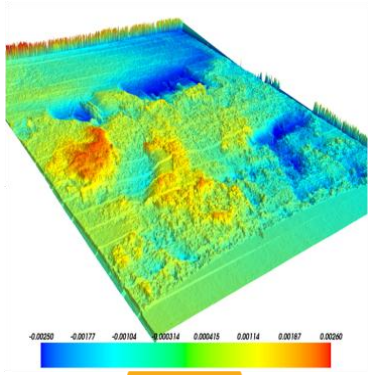


Main achievements :

- Definition of 11 application cases
- Preparation of mock-ups, specimens, flaws, reference blocks

Industrial fields :

- Steel
- Nuclear
- Aeronautics
- Automotive



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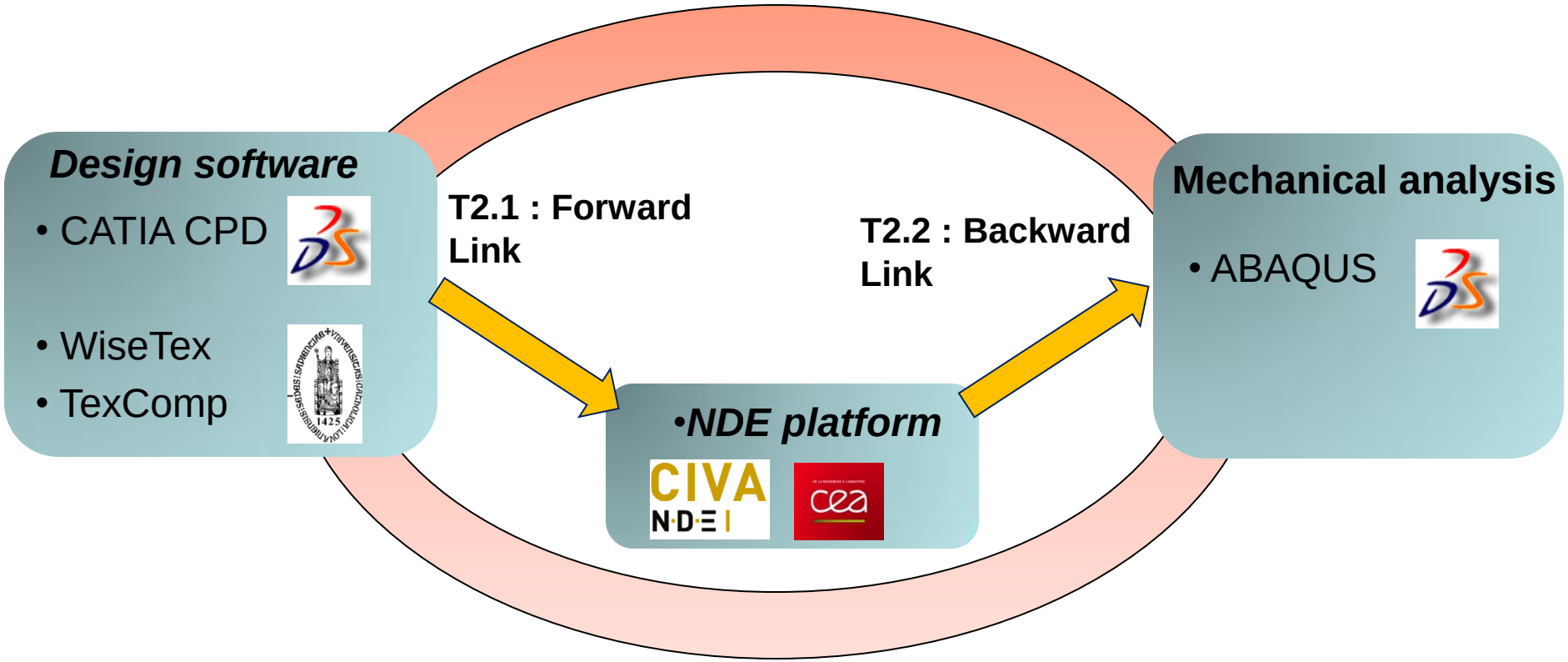
WP2 : Platform interoperability

Lead: EADS

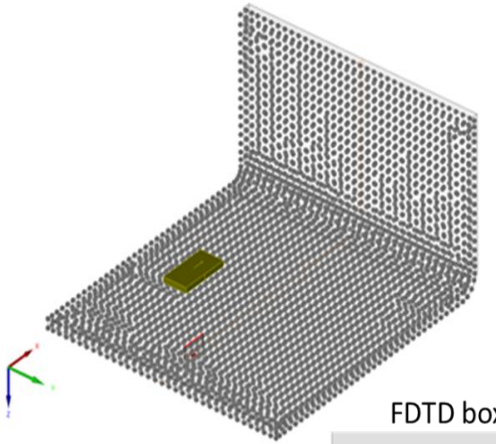
Involved partners : KATHOLIEKE UNIVERSITEIT LEUVEN, DS, cea



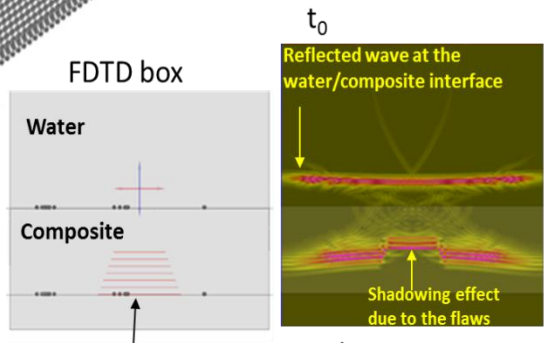
T2.3 : Software engineering solutions for platform integration

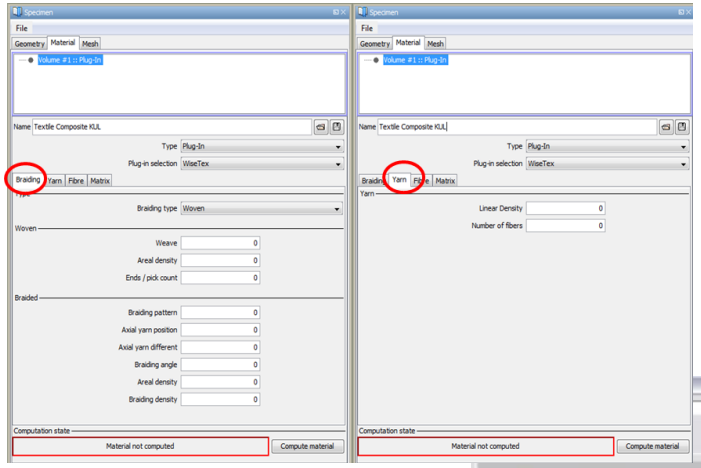
WP2 : Platform interoperability

- **T2.1: Forward Link (Composite design > CIVA):**
  - CATIA Composite Design > CIVA (.inp format files)
  - WiseTEX (KU Leuven) connected to CIVA

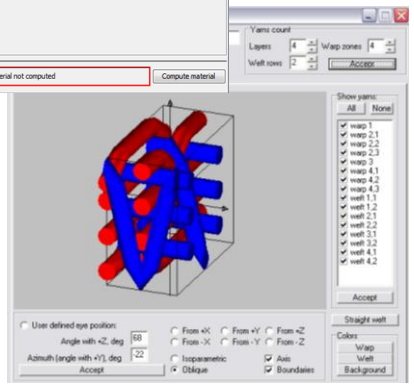


CATIA



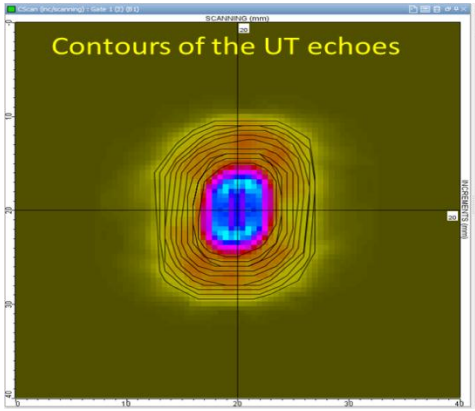


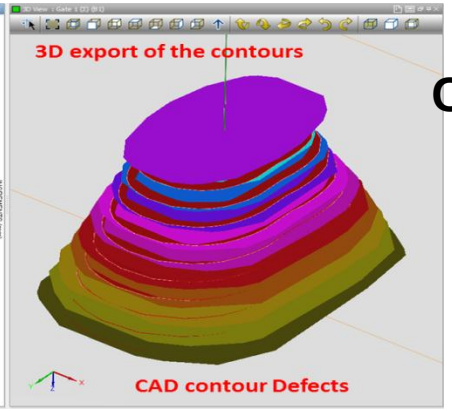
WiseTex



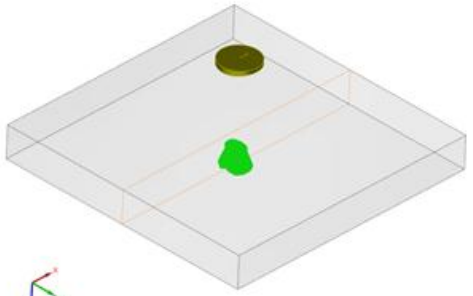
WP2 : Platform interoperability

- **T2.2: Backward Link (CIVA > Mechanical analysis): « Effects of defects »**
  - Imaging of flaws: Segmentation (CEA), TDTE (EADS)
  - Export of the flaw to ABAQUS (Mechanics code) as contours or clouds

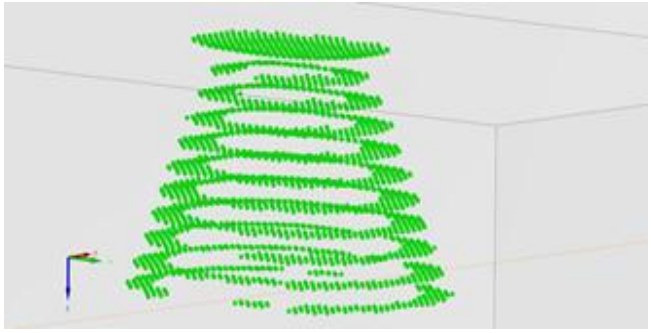




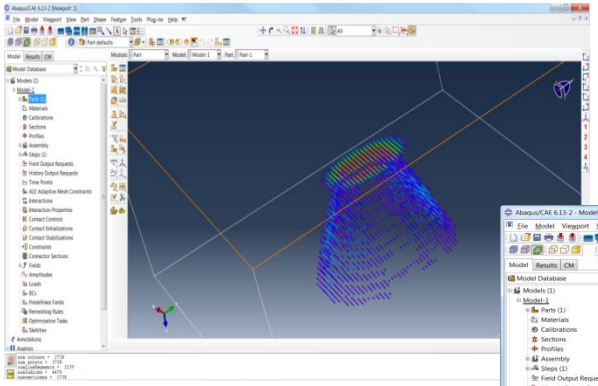
CIVA

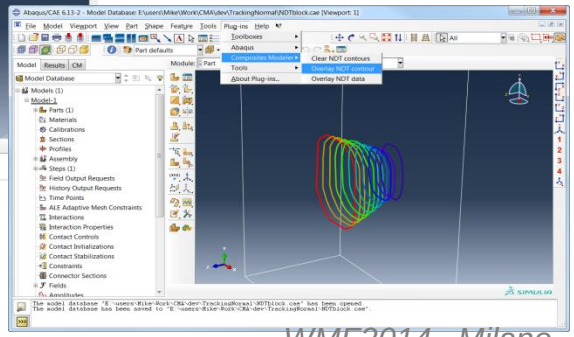


Filtering, discretization as a set of points



ABAQUS





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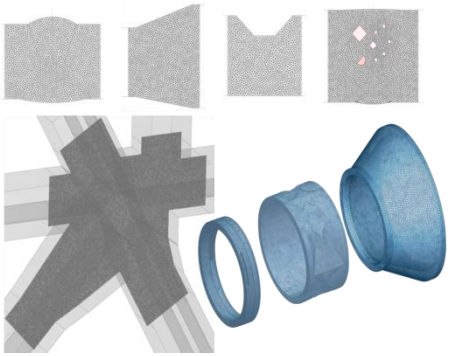
WP3 : UT simulation codes

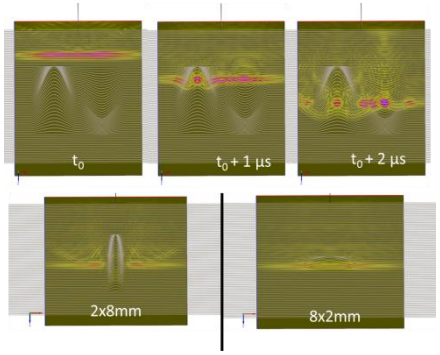
Lead: Imperial College London

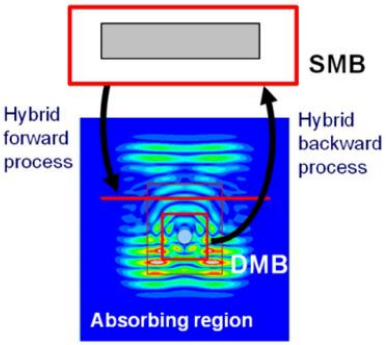
Involved partners : cea, EADS, Fraunhofer IZFP, INRIA

Tasks:

- **T3.1 : Numerical tools**
- **T3.2 : Simulation of ultrasonic scattering**
- **T3.3 : Hybrid modules**
- **T3.4 : Integration of the UT simulation modules**







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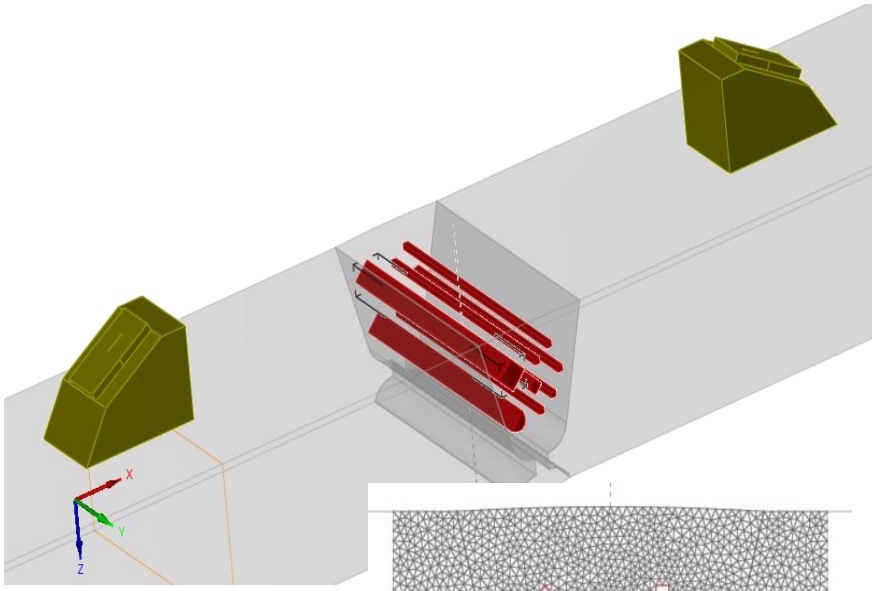
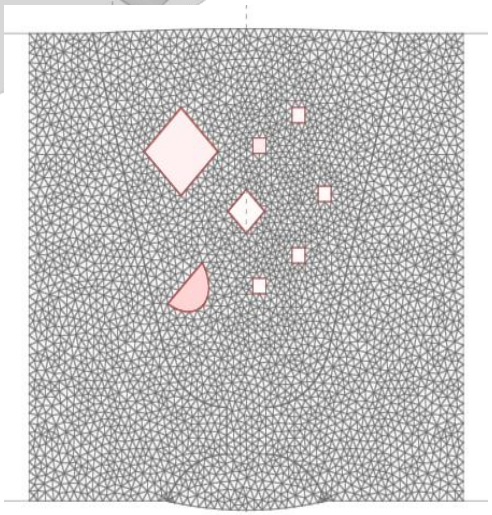
WP3 : Meshers: connexion with GMSH

2D meshing

heterogeneous material+ flaws



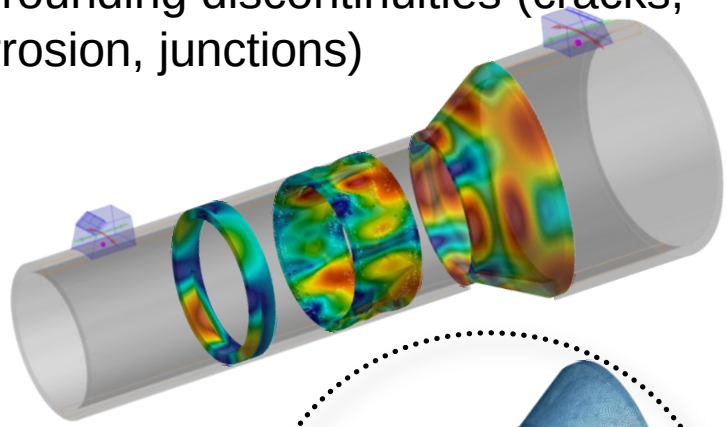


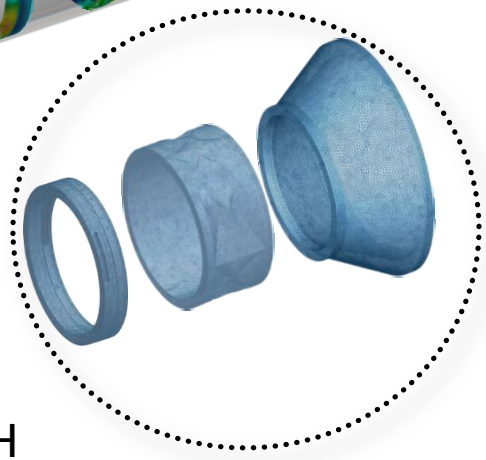
2D FEM mesh with GMSH

3D meshing

Several 3D FEM boxes

Calculations within FEM boxes surrounding discontinuities (cracks, corrosion, junctions)





3D FEM meshes with GMSH

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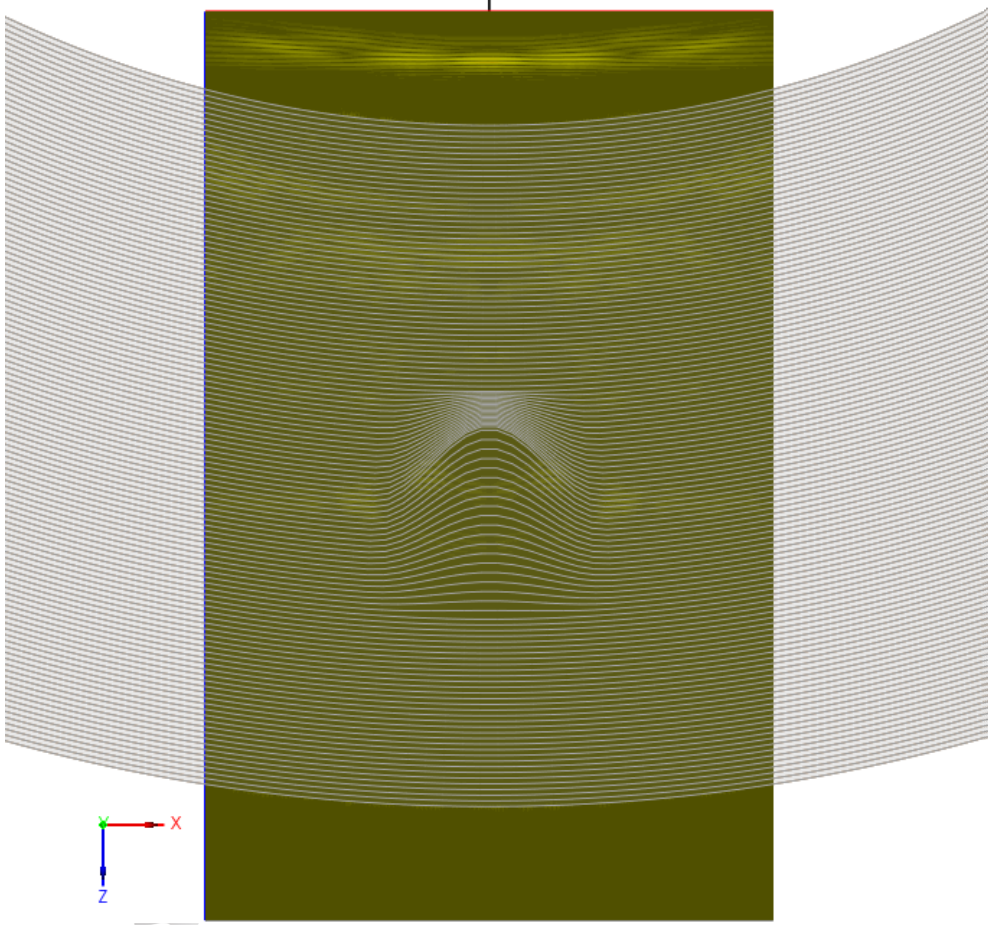
WP3: Hybrid models (Analytical/FE code)

CIVA/ACEL-NDT EADS

- Reciprocity method, coupling in the fluid
- *Quantities : particle velocity (incident/scattered)*



Achievements :

- Implementation in CIVA achieved (2D version)

In progress :

- Tests and Validation of the 2D model (CEA/EADS)
- 3D version (EADS)

WP4 : ET simulation codes

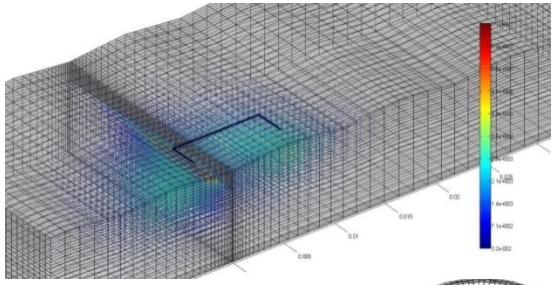
Lead: Fraunhofer IZFP

Involved partners :

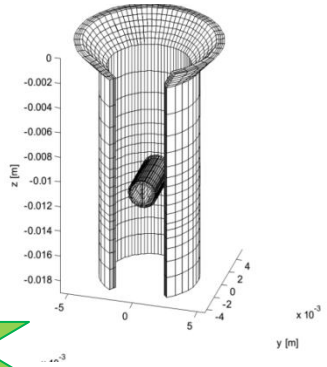
Tasks:

- **T4.1 : Numerical tools for ET NDE simulation**
- **T4.2 : Simulation of the 3MA method**
- **T4.3 : Simulation of ET NDE from defects**
- **T4.4 : Integration of the ET simulation modules**

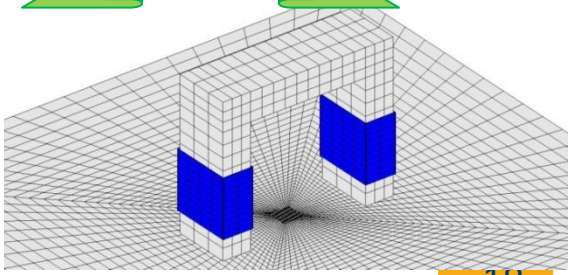
Case #1



Case #3



Case #10



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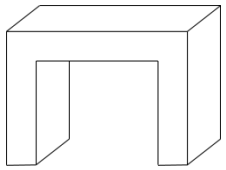
WP4 : ET simulation codes

Fraunhofer IZFP

•Preparation → •Parametric model → •Simulation → •Evaluation, visualization → •Validation

MATLAB R2010a

•3MA probe type



•Specimen data

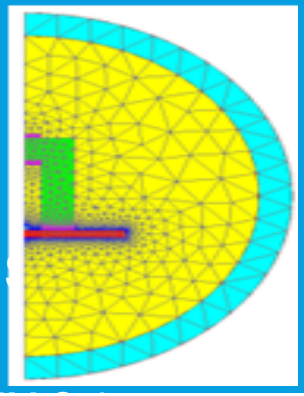
•NDT method
- IP
- AH
- EC

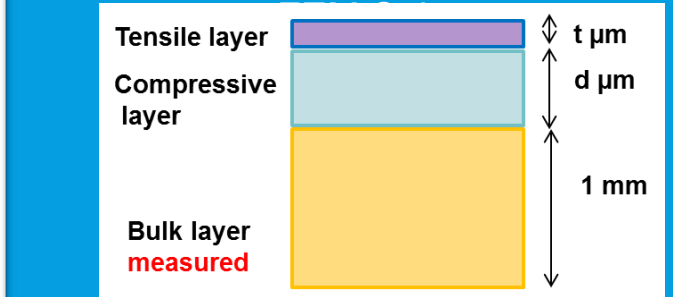
•Parametric model of the inspection situation

•Settings

•(Excitation magnitude, frequency)

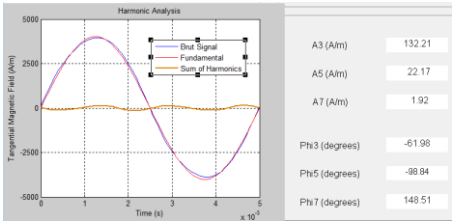
•FEM



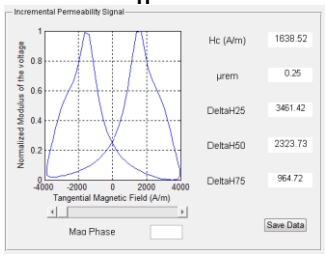


MATLAB R2010a

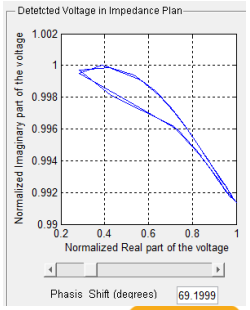
•HA



•IP



•EC



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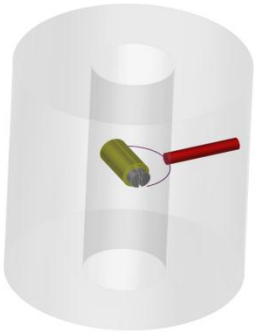
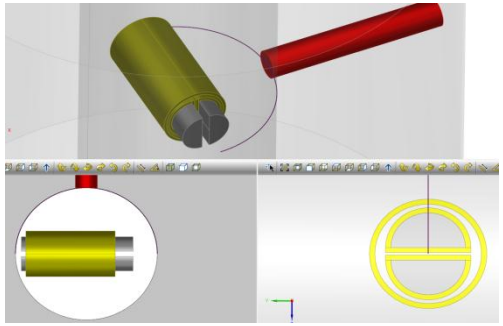
WP4 : ET simulation codes

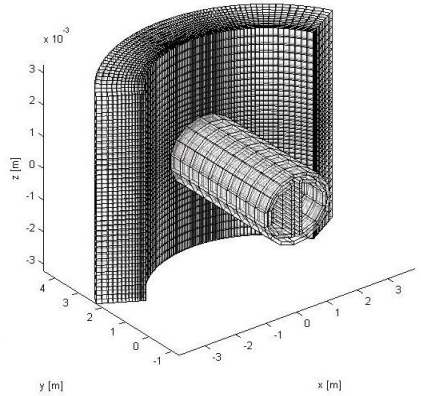
- **T4.3 : Simulation of ET NDE signals from defects**
  - Complex geometries
  - Complex materials (gradient of conductivity/permeability)
  - Complex probes

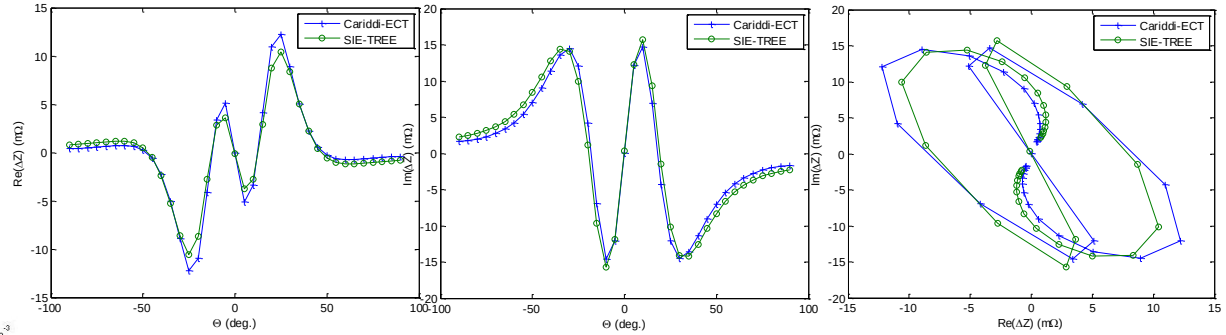




Hybrid Code : CEA

FEM Code : Univ. Cassino/Napoli





To be compared with experimental data from EADS

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WP5 : Application and validations

Lead: amec

Involved partners :

All (industrial users + modeling partners)

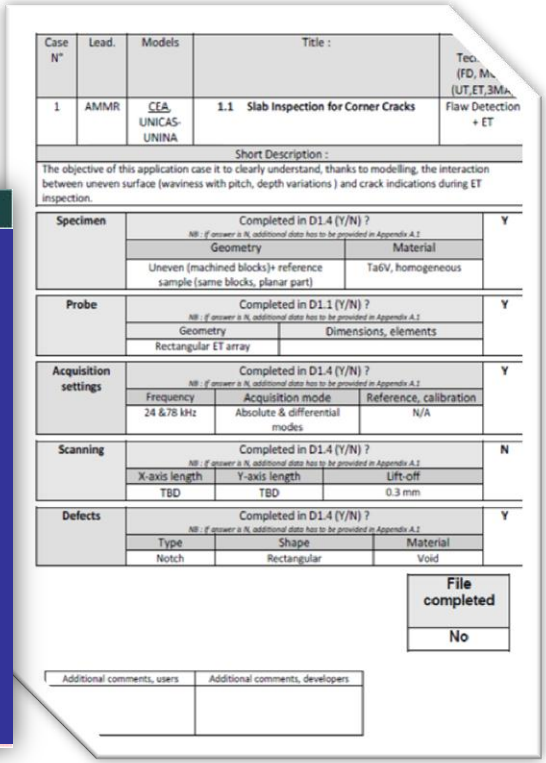
Tasks:

- **T5.1 : Tests and validation**
- **T5.2 : Applications and evaluation of the simulation tools**

Main achievements :

- Collection of experimental data by partners
- Application summary document + « Validation » check-list
- Comparisons in progress for all application cases

N°	Lead:	Short name	Type	Technique	Complexity issues	Models to be developped	Models Partners
1	AMMR						
2	EADS						
3	EADS						
4	3ERCO						
5	AMMR						
6	SSF						
7	SKF						
8	SKF						
9	SKF						
10	VW						
11	VW						



Case N°	Lead.	Models	Title :	Tec. (FD, M.. (UT,ET,3MA..
1	AMMR	CEA, UNICAS-UNINA	1.1 Slab inspection for Corner Cracks	Flaw Detection + ET

Short Description :

The objective of this application case it to clearly understand, thanks to modelling, the interaction between uneven surface (waviness with pitch, depth variations) and crack indications during ET inspection.

Specimen	Completed in D1.4 (Y/N) ?		Y
	Geometry	Material	
	Uneven (machined blocks)+ reference sample (same blocks, planar part)	Ta6V, homogeneous	
Probe	Completed in D1.1 (Y/N) ?		Y
	Geometry	Dimensions, elements	
	Rectangular ET array		
Acquisition settings	Completed in D1.4 (Y/N) ?		Y
	Frequency	Acquisition mode	Reference, calibration
	24 &78 kHz	Absolute & differential modes	N/A
Scanning	Completed in D1.4 (Y/N) ?		N
	X-axis length	Y-axis length	Lift-off
	TBD	TBD	0.3 mm
Defects	Completed in D1.4 (Y/N) ?		Y
	Type	Shape	Material
	Notch	Rectangular	Void

File completed
No

Additional comments, users	Additional comments, developers

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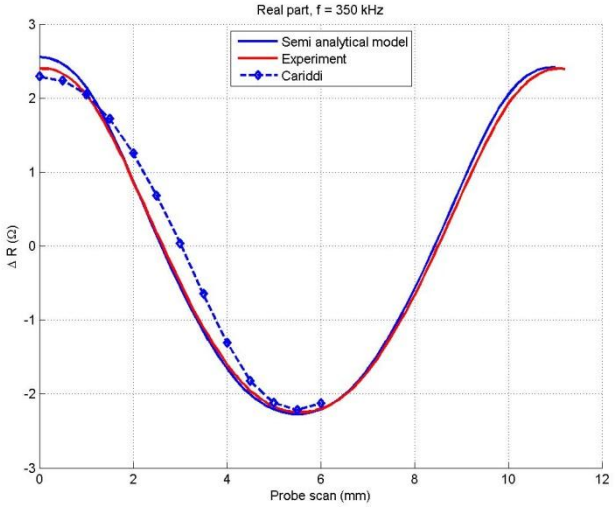
WP5 : Application and validations (ET)

Case #1

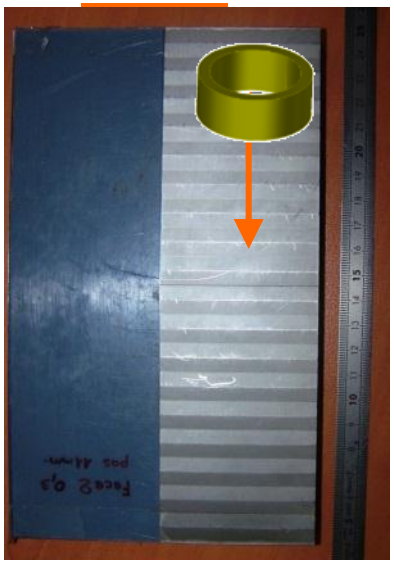
•CARIDDI_ECT and CIVA vs. CEA experimental data



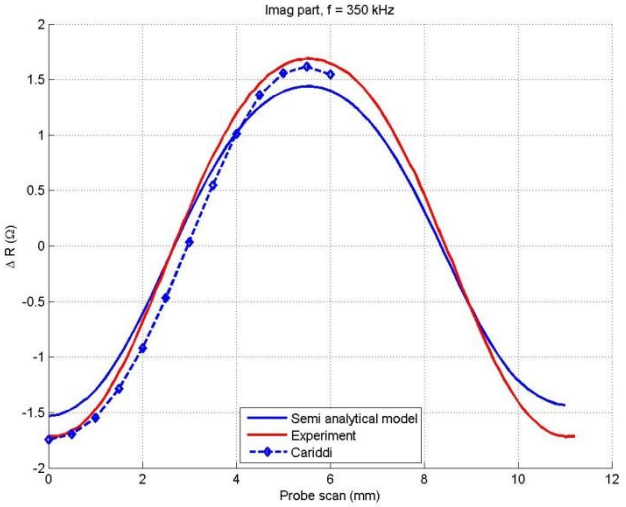
Wavy part of the specimen

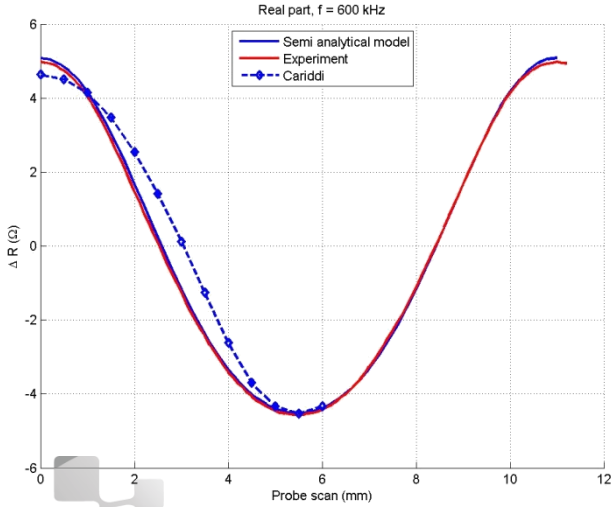
Without defect

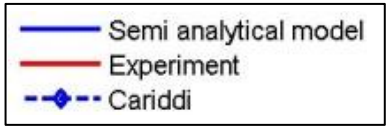
Circular coil

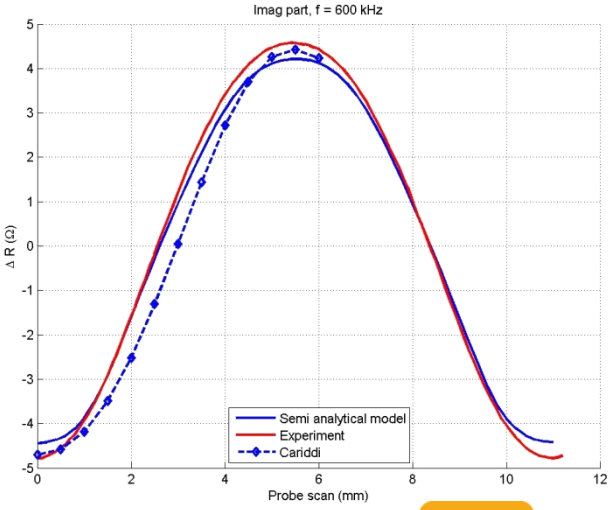


Coil scan over the flaw-free part of the mock-up









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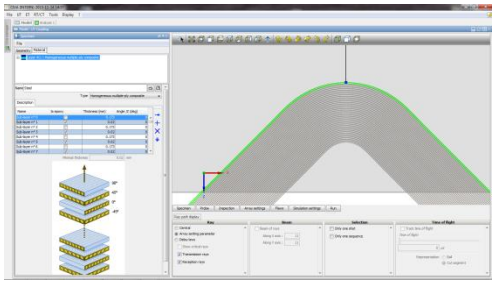
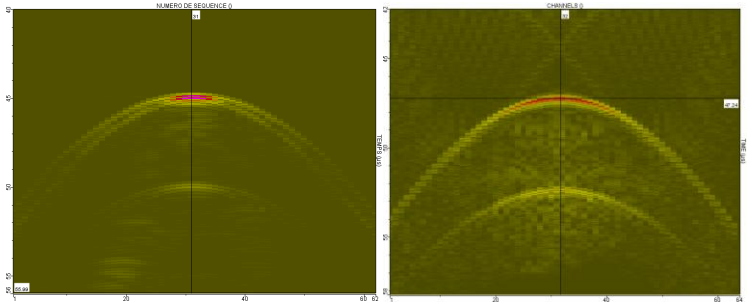
WP5 : Application and validations (UT)

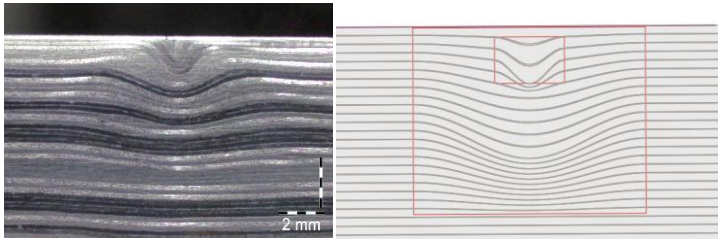
Simulation of UT inspections of composites

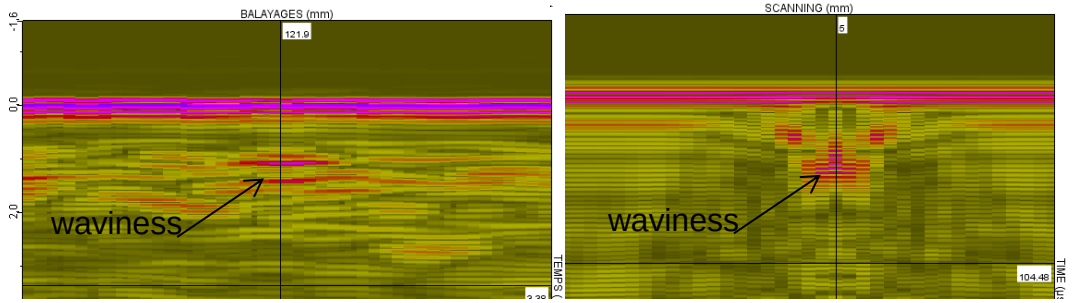
- Curved composites (critical parts)



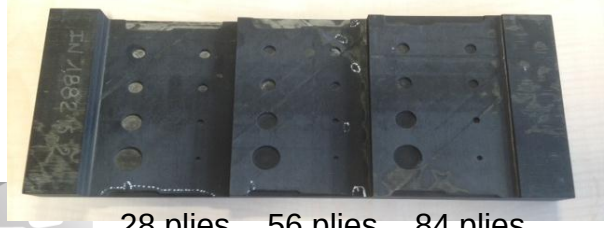


- Ply waviness (flaws at manufacturing stage)

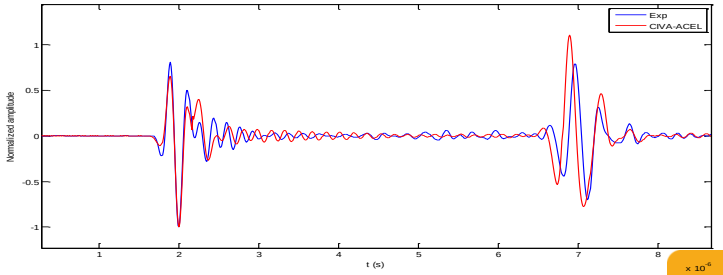




- Calibration blocks (reference flaws)



28 plies 56 plies 84 plies



SIMPOSIUM
Interoperable NDE simulation tools

WP6 : Valorization and Dissemination

Lead: EXTENDE CIVA

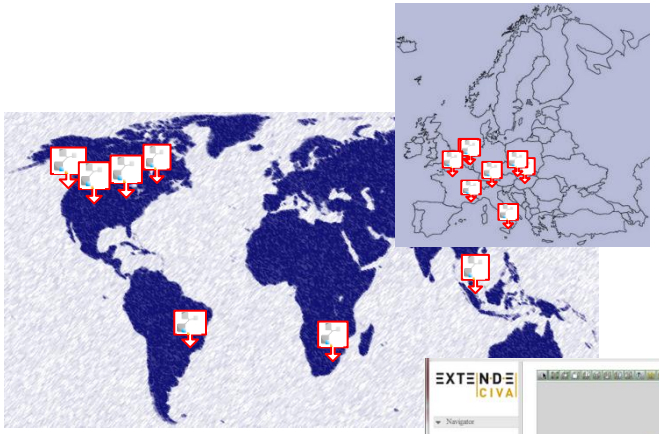
Involved partners : **All**

Tasks:

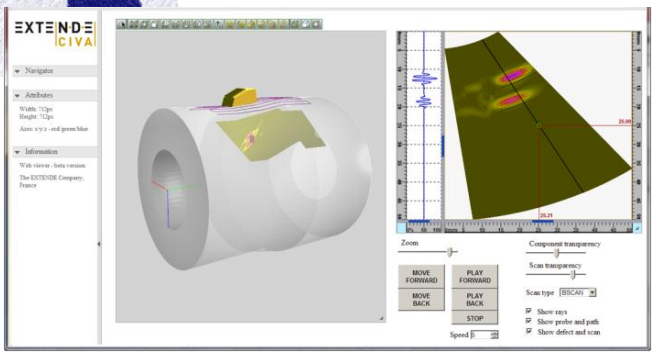
- **T6.1 : Web-suited modeling, simulation and visualization of NDE**
- **T6.2 : SIMPOSIUM dissemination**
- **T6.3 : SIMPOSIUM exploitation**

Main achievements :

- Rather strong dissemination through communications/publications
- Training session/dedicated session to be held during the European Conference in NDT (Praha)
- User-interactive Web-Tools
- Exploitation roadmap of simulation tools discussed with involved partners



Fraunhofer IZFP



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WP6 : Valorization and Dissemination

ASNT Fall Conference 2012
The American Society for Nondestructive Testing
Orlando, USA, October 29th – November 2nd 2012

MENDT 2012
6th Middle East Nondestructive Testing Conference & Exhibition
Bahrain, October 7th-10th 2012

ISEUT 2012

ISEUT 2012
with our partner Matrix
2012 International Symposium on Development of Electromagnetic and Ultrasonic Testing Technology
Nanchang, Chine, August 17th-19th 2012

QNDE 2012
Conference on Quantitative Non Destructive Testing
Denver, USA, July 15th-20th 2012

CONAEND 2012
16th International Conference on Evaluation of Integrity and Extension of Life of Industrial Equipment
Sao Paulo, Brazil, July 16nd-19th 2012

ICNDE 2012
9th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components
Seattle, USA, May 22nd-24th 2012

ESOPE 2013
Leading pressure equipment tradeshow in the international marketplace
Paris, France, October 8th – 10th 2013

NDT in Canada Conference 2013
The Canadian Institute for NDE (CINDE) is providing a conference for the NDT community
Calgary, Canada, October 7th-10th 2013

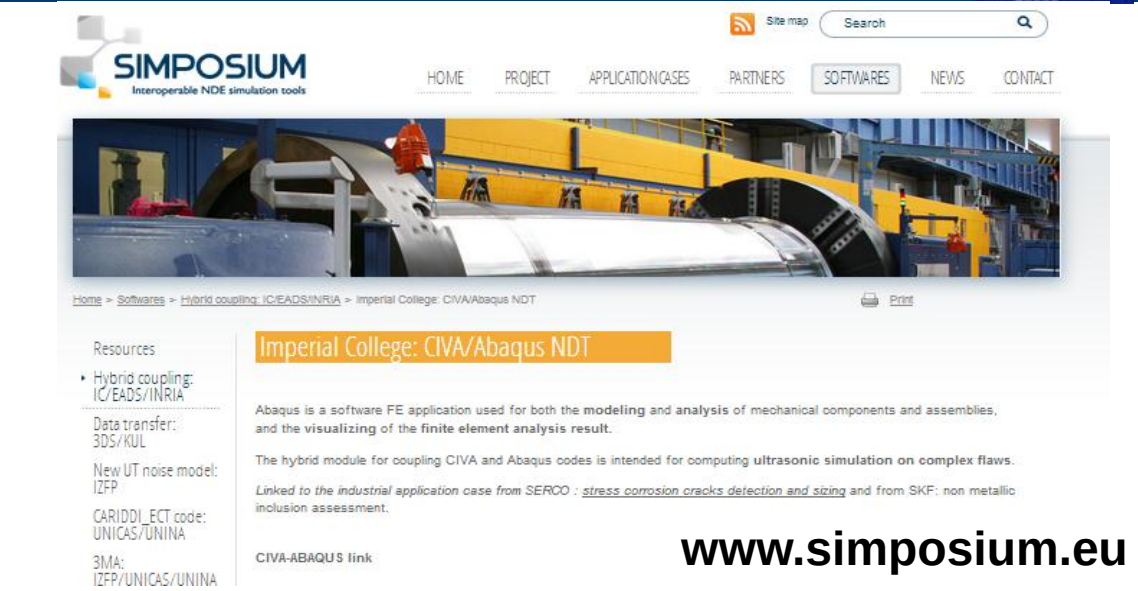
10th International Conference on NDE
10th International Conference on NDE in relation to structural integrity for nuclear and pressurized components
Cannes, France, October 1st-3rd 2013

Materials Testing 2013
Annual conference of the British Institute of NDT
Telford, UK, September 10th-12th 2013

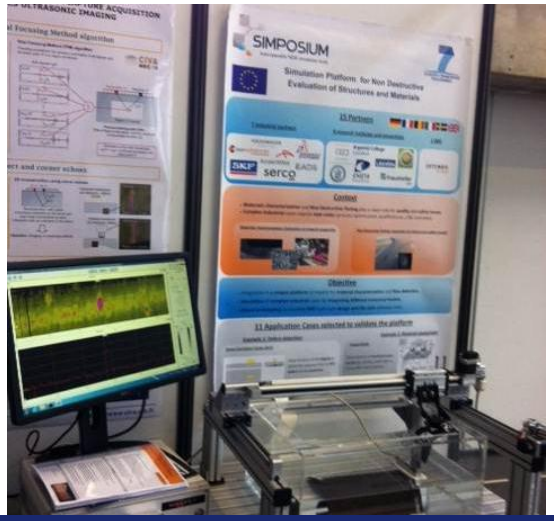
QNDE 2013
Conference on Quantitative Non Destructive Testing
Baltimore, USA, July 21st-26th 2013

SINCE 2013
2nd Singapore International NDT Conference & Exhibition
Singapore, Singapore, July 19th-20th 2013

COTEQ 2013
12th Conference on technologies and Equipments in NDT
Porto de Galinhas, Brazil, June 18th-21st 2013



www.simposium.eu



ENDE 2013
18th International Workshop Electromagnetic Nondestructive Evaluation

NDCM-XIII 13th International Symposium on Nondestructive Characterization of Materials
University of Maine
May 20-24, 2013
Palais des Congrès et de la Culture du Mans, France

Conclusion

Main results achieved so far (Project ends on Dec 2014):

- **11 application cases driven by industrial end-users**

(Nuclear, Energy, Steel, Transport, automotive)

- **In progress : Simulation and validations with experimental data**
- UT and ET codes developped (new formulations or extensions of existing codes)
- Integration and/or connexion to CIVA achieved
- **Feasibility studies conducted for the forward/backward links**

(Design / NDT / Mechanics)

- Significant dissemination (communications, articles)

Remaining tasks :

- **Investigations of mismatch simulation/experiment for some application cases**
- **Training session (ECNDT 2014, Prague, October 2014)**

SIMPOSIUM
Interoperable NDE simulation tools

What does SIMPOSIUM bring to industry ?

Basically : tools for **improved product quality check** through…

- **Prediction of inspection performances**
- **Understanding of most influent parameters**
- **Conception of new methods**
- **Qualification**
- **Training for NDT inspectors**

+

- **(Preliminary) Tools for predicting the remaining useful lifetime of structures**

Feasibility studies carried out over composites cases …

…But still some works to do with multi-disciplinay cross-cutting issues

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Interoperable NDE simulation tools

What's next ?

NDE and MC simulation platform is now mature and could (should) be

- linked with :
  - Mechanics, fracture, analysis (estimation of RUL)
  - Ageing, damage and degradation modeling tools
  - virtual and augmented reality tools, cyberphysical systems (augmented NDE within the manufacturing)
  - Probabilistic, risk based inspection tools
  - Automated (robotic) inspection

- Used for generating a NDE data base to train operators, to test new methods or innovative signal processing / imaging /diagnosis

Potential (and on-going discussions) contributions within H2020:

from FoF8 to FoF12

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