POLITECNICO
MILANO 1863

DIPARTIMENTO DI MECCANICA
mecc

Politecnico di Milano

Dipartimento di Meccanica

SIGMALab

OVERVIEW AND EXPERTISE

(June 2018)

SIGMA Lab

Structure Impact proGnosis Monitoring MAterial LABoratory

Politecnico di Milano, since 1863

Faculty & Students AY 2015/2016

Architecture

Professors & Researchers	Students
297	6,957

Design

Professors & Researchers	Students
94	3,542

Engineering

Professors & Researchers	Students
925	27,485

Professors and Assistant Professors	1,316
Technical and Administrative staff	1,207
PhD students	1,011
Students	37,984

Politecnico di Milano: internationalisation at home

International students coming from more than 100 countries

- ✓ **1513 at BSc (6%)**
- ✓ **2102 at MSc (23%)**
- ✓ **312 Ph.D. (29%)**

Specializing Master and Short post-graduation courses

- ✓ **More than 2500 students (20% from foreign countries)**

QS World University Rankings by Subject 2016

	World	EU	Italy
Engineering & Technology	**24**	**7**	**1**
Architecture & Built Environment	15	6	1
Art & Design	10	3	1
Computer Science & Information Systems	43	9	1
Chemical Engineering	51	11	1
Civil & Structural Engineering	14	5	1
Electrical & Electronic Engineering	44	11	2
Mechanical, Aeronautical & Manufacturing Engineering	18	6	1
Materials Sciences	51	12	1
Mathematics	51	14	1
Business & Management Studies	51	15	2
Physics & Astronomy	51	20	2

QS World University Rankings by Subject 2016

	World	EU	Italy
Engineering & Technology	**24**	**7**	**1**
Architecture & Built Environment	15	6	1
Art & Design	10	3	1
Computer Science & Information Systems	43	9	1
Chemical Engineering	51	11	1
Civil & Structural Engineering	14	5	1
Electrical & Electronic Engineering	44	11	2
Mechanical, Aeronautical & Manufacturing Engineering **(2018)**	**17**	**5**	**1**
Materials Sciences	51	12	1
Mathematics	51	14	1
Business & Management Studies	51	15	2
Physics & Astronomy	51	20	2

The 12 Departments of the Politecnico di Milano

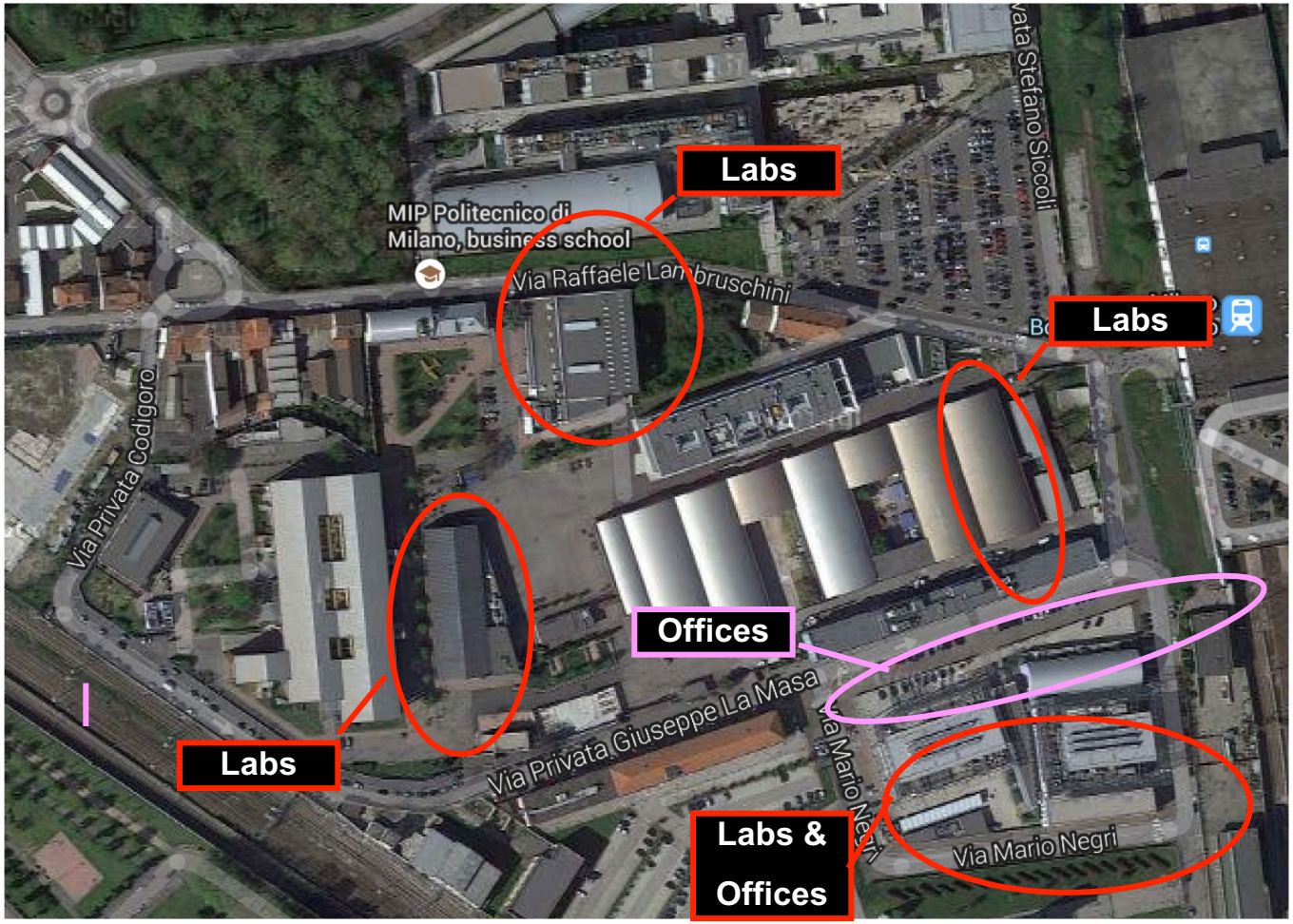
- Aerospace Science and Technology
- Architecture and Urban Studies
- Architecture, Built Environment and Construction Engineering
- Chemistry, Materials and Chemical Engineering “Giulio Natta”
- Civil and Environmental Engineering
- Design
- Electronics, Information and Bioengineering
- Energy
- Management, Economics and Industrial Engineering
- Mathematics
- **Mechanical Engineering**
- Physics

Department of Mechanical engineering: people

Mission Statement

With its large-scale state-of-the-art technological infrastructure and research facilities, broad theoretical, methodological and technological knowledge, international reputation and successful alumni, the overall mission of the Department of Mechanical Engineering is to deliver **world-class research and education in Mechanical Engineering, with particular regard to their application in industry**.

Department of Mechanical engineering: Milano-Bovisa Campus (since 1998)



Department of Mechanical engineering: offices and laboratories

Two new buildings at the Bovisa Campus:

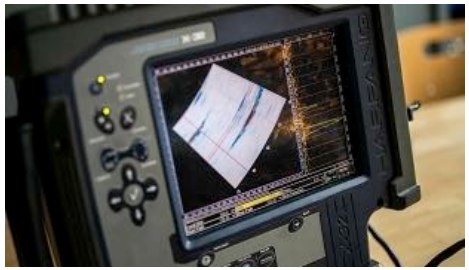
- the first was inaugurated in December 2007 and hosts offices and labs;
- the second was inaugurated in July 2014 and hosts offices. Both are in Via La Masa.

	Offices [m^2]	Labs [m^2]
Campus Bovisa South	3127	3167
Campus Bovisa East (LaST Labs)	60	1960
Lecco Campus	200	470
Piacenza Campus and MUSP Labs		1300
Total	**4325**	**8037**

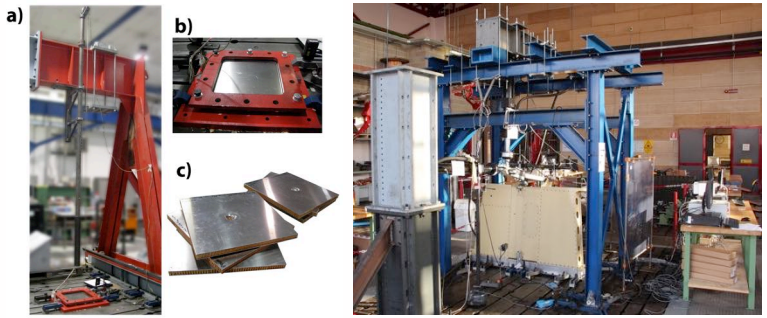
Average laboratory area of 80 m^2/researcher

Department of Mechanical engineering: laboratories

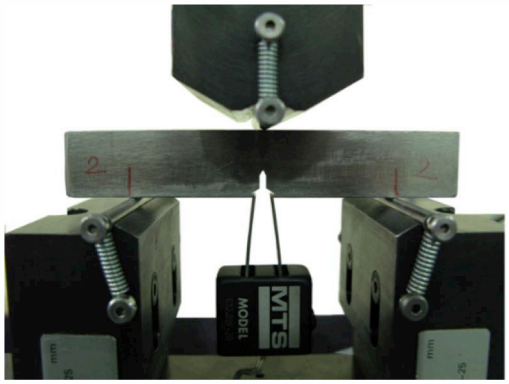
Wind tunnel

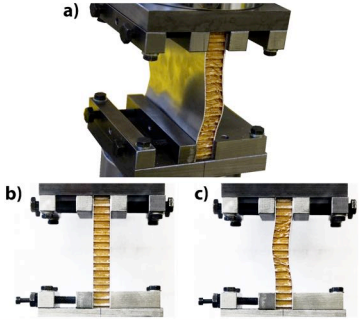


Structures Facility



Material Facility



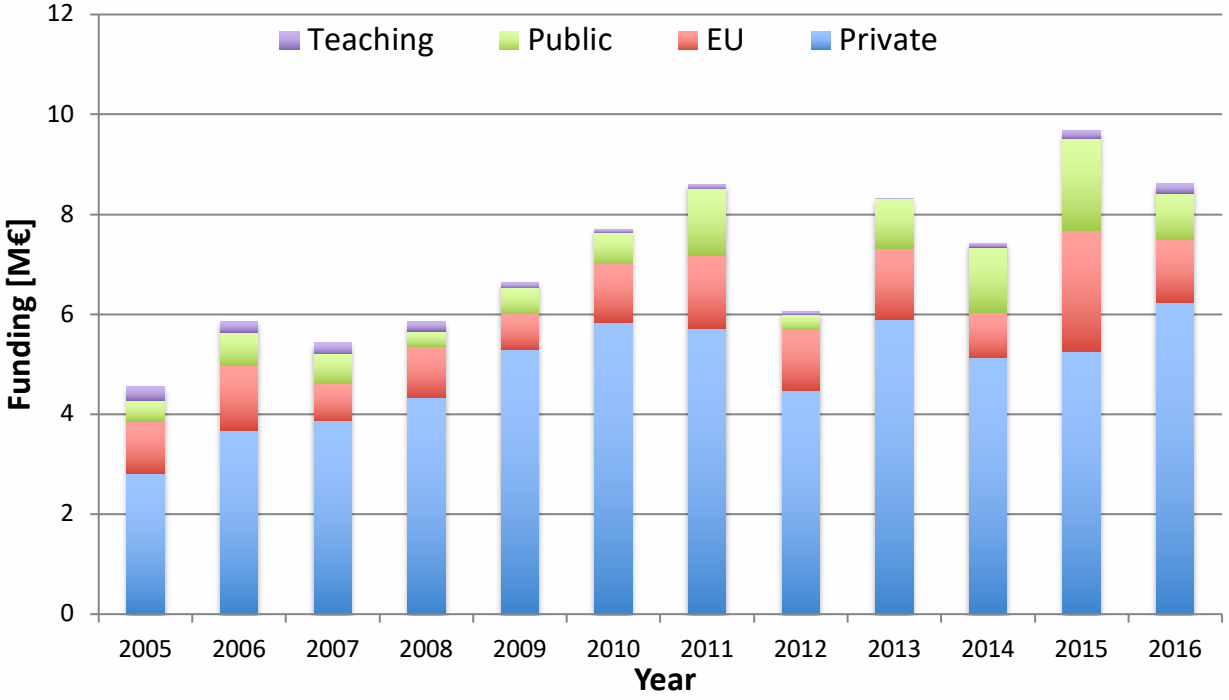


- **Laboratory of Mechanical Department allow tests of specimens, components up to full scale large/complex systems**
- Expertise in certification tests (FAA)

Department of Mechanical engineering: fundings

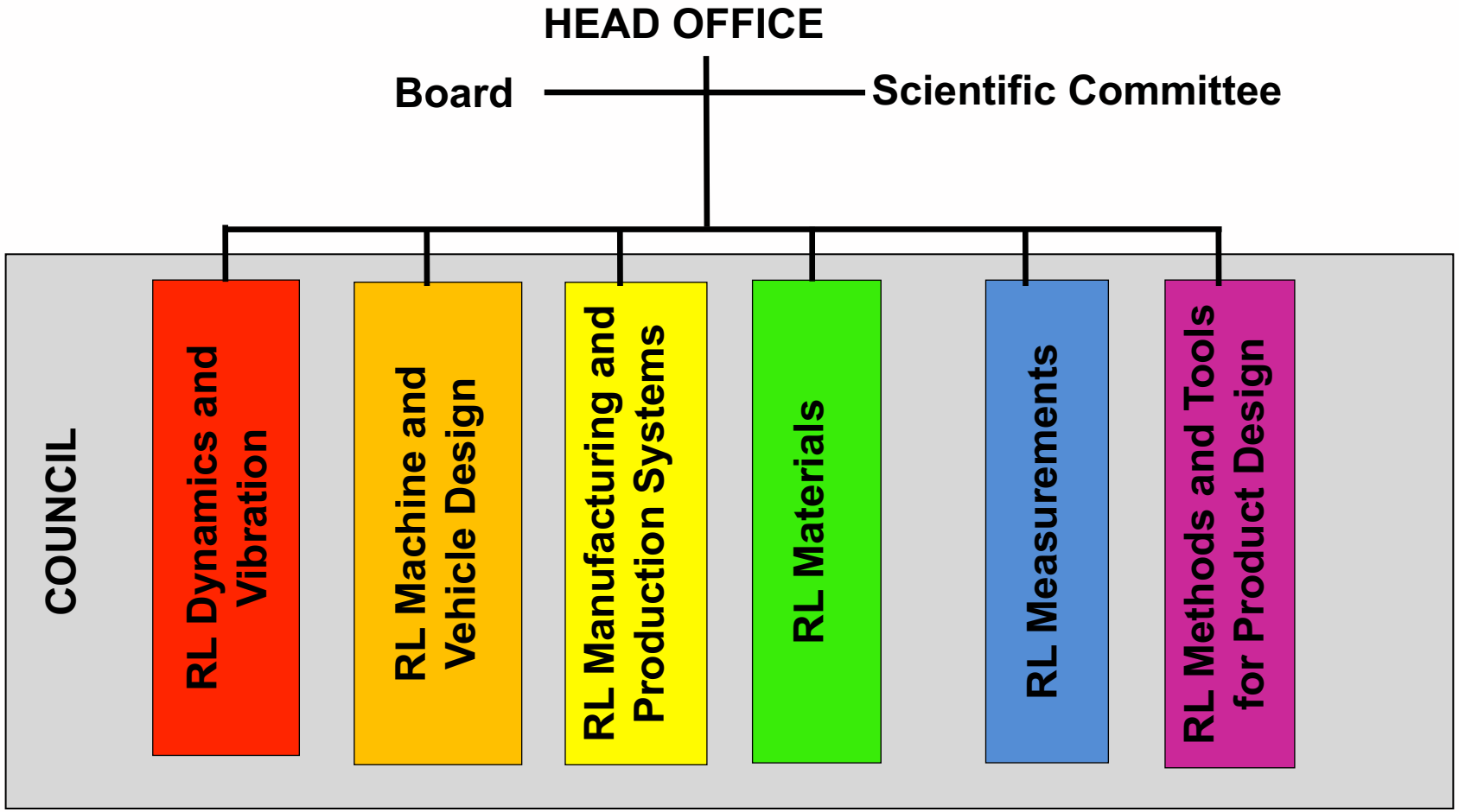
Research funding has reached about 100 k€/researcher (105 people permanent staff).

Most of the research funding comes from private partners. Other funding comes from the European Union and the Italian Ministry.



- ✓18 EU-funded projects currently active
- ✓11 new EU projects started in 2015
- ✓5 new EU projects started in 2016 (September)
- ✓21 EU projects started in the last 4 years (Jan 2013-Sept.2016)

Department of Mechanical engineering: research lines



Our research team inside Politecnico di Milano
SIGMALab, http://www.giglio.faculty.polimi.it

Politecnico di Milano …since 1863… → 12 departments – more than 1300 Researchers/Professors – more than 37.000 students

⬇

Department of Mechanical Engineering → More than 105 people as permanent staff – more than 100 PhD students – approximately 9-10 M€ of annual funding (Mainly from EU and Industry)

http://www.mecc.polimi.it/

⬇

Research lines → Dynamics and Vibration of Mechanical Systems, Ground Vehicles, History of Technology, *Machine Design,* Manufacturing and Production Systems, Materials, Measurements and Experimental Techniques, Methods and Tools for Product Design

⬇

•Structural Integrity of Mechanical Components and Systems – SI ←

⬇

SIGMA Lab ***Structure Impact proGnosis Monitoring MAterial LABoratory***

Research group (devoted to research in defense field)

SIGMALab: People

Team Leader

Marco GIGLIO
Full Professor, Deputy Director MECC
Politecnico di Milano
Dipartimento di Meccanica
(Department of Mechanical Engineering)
Milano Bovisa - Via La Masa 1
Building B22
20156 Milano - ITALY
Tel: + 39 02 2399 8234
Fax: + 39 02 2399 8202
Tel secretary: + 39 02 2399 8212
e-mail: marco.giglio@polimi.it
Skype: marco.giglio1
web: www.mecc.polimi.it

Research Team

Andrea MANES Ph.D.
Associate Professor, Scientific Manager
Programme head of Structural Integrity under Extreme Load
andrea.manes@polimi.it
Tel: + 39 02 2399 8630

Claudio SBARUFATTI Ph.D.
Research Fellow - Assistant Professor
Programme head of Structural Health Monitoring and Prognosis
claudio.sbarufatti@polimi.it
Tel: + 39 02 2399 8213

Francesco CADINI Ph.D.
Research Fellow - Assistant Professor
Reliability and statistical approaches for structural integrity
francesco.cadini@polimi.it
Tel: + 39 02 2399 6355

Massimo FOSSATI Ph.D.
Research Fellow

Mauro SALVETTI
Research Fellow

Demetrio CRISTIANI
Research Fellow

Alessio BELIGNI
Ph.D. graduate student

Stefano CARDAMONE
Ph.D. graduate student

Luca COLOMBO
Ph.D. graduate student

Riccardo SCAZZOSI
Ph.D. graduate student

Simone LOMBARDO
Ph.D. graduate student

Dayou MA
Ph.D. graduate student

SIGMALab: outlook of the research team

Our mission:

Main aim of the research team is an advanced engineering approach for the **assessment, new design and optimization of mechanical and aerospace components**. Research activities and topics concern with several aspects related to:

- **assessment and optimization** of components under spectrum loads and extreme loads (ballistic damage, etc.);
- **monitoring, diagnosis and prognosis** of critical structures subject to degradation, under fatigue loads and impact loads;
- **application of novel probabilistic approaches** in structural integrity design (flaw tolerant approach, reliability methods, vulnerability, etc.).

Experimental investigations and numerical-analytical investigation allow to individuate models able to simulate components under contingent-extreme loads in order to optimize their behavior.

SIGMALab: outlook of the research team

Our vision: a reference team for tailored assessment of critical components under extreme conditions

More that 15 years of challenging research activities with academic and industrial partners and customers (included security and defense).

SIGMALab: research Areas

SIGMALab is active in several research topics related to defense field, but conventionally we have created two main research programmes. Each area develops original and advanced technology platforms at the state of the art in order to deliver the best solutions for challenging problems. The areas merge in several activities.

Structural integrity under extreme load

- Large deformation and failure, ballistic and low velocity impact, explosion, crack and damage, delamination, etc
- Definition of optimal protection
- Material calibration exploiting innovative constitutive law
- Numerical modelling (FEM, DEM, meshless, etc)
- Analytical modelling
- Experimental testing (from micro to full cale)

Model-based Structural Health Monitoring and prognosis

- Investigation of different state of art sensor technologies for SHM
- Numerical and analytical modelling for SHM system training
- Machine learning and pattern recognition for diagnosis
- Bayesian filters and Monte-Carlo methods for prognosis
- Experimental SHM verification and performance qualification

SIGMALab: research Areas

New entries for SIGMALab research topic

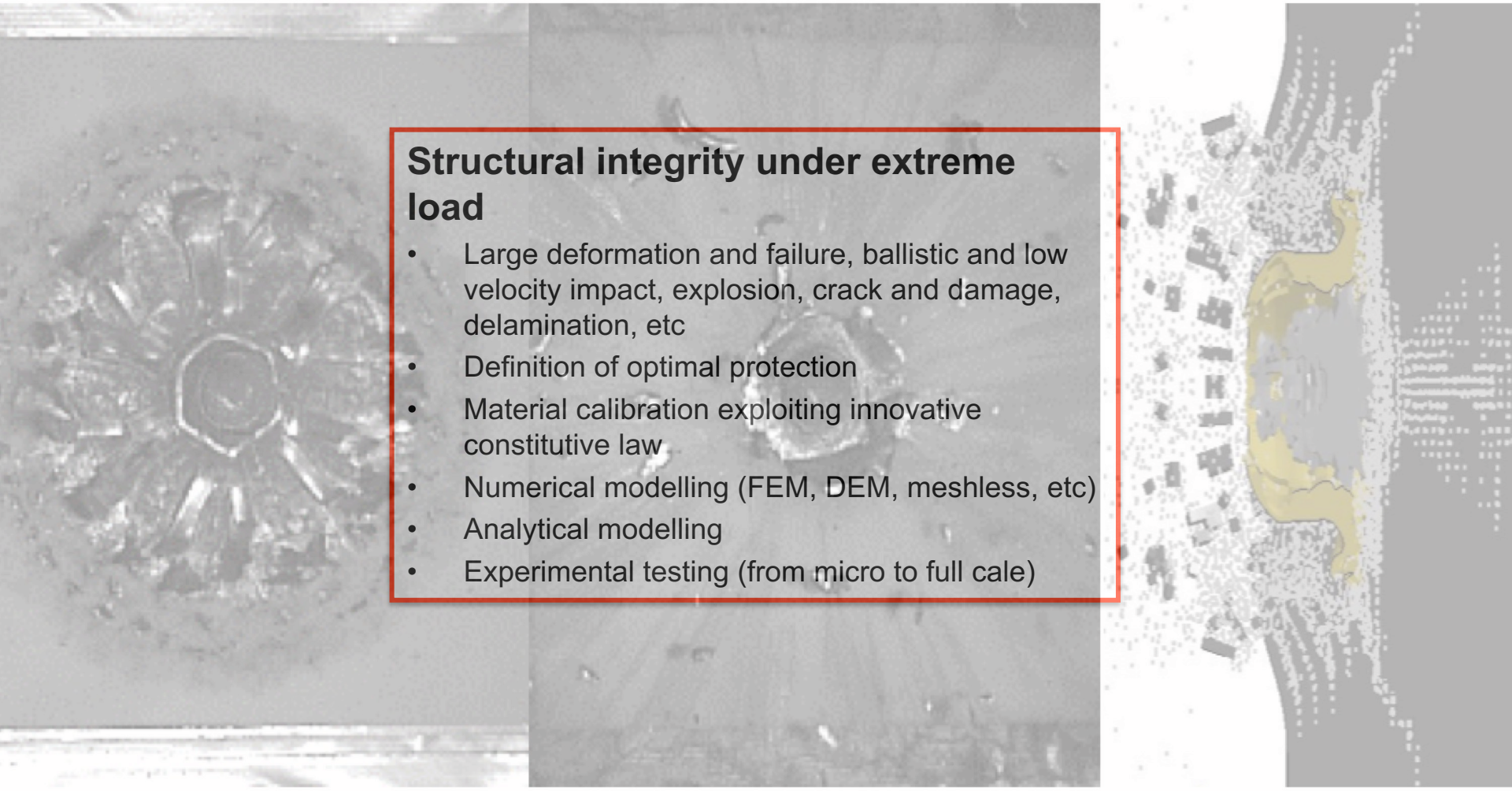
Energy

- SIGMALab team is working in order to provide dedicated solutions both for O&G and renewable energy (explorative drilling and innovative solar troughs).

Reliability and statistical approaches for structural integrity

- Numerical and analytical modeling
- Machine learning and pattern recognition for cheap approximation of complex FEM responses
- Monte-Carlo simulation schemes for uncertainty effects quantification
- Advanced optimization schemes (evolutionary algorithms, etc.)

SIGMALab: research Areas

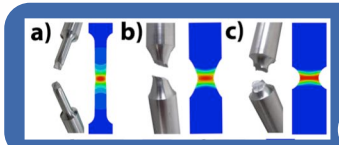


Structural integrity under extreme load

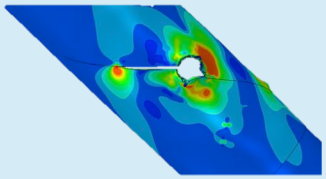
- Large deformation and failure, ballistic and low velocity impact, explosion, crack and damage, delamination, etc
- Definition of optimal protection
- Material calibration exploiting innovative constitutive law
- Numerical modelling (FEM, DEM, meshless, etc)
- Analytical modelling
- Experimental testing (from micro to full cale)

Outlook of the framework: a fit for purpose / multidisciplinary technology platform

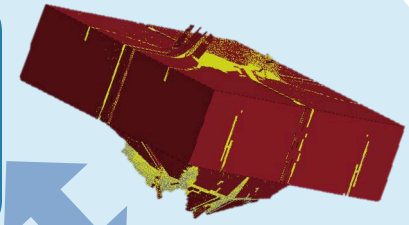
A deep investigation both in practical aspects and state of the art

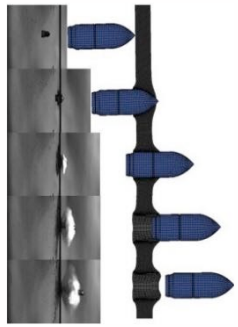


Material calibration

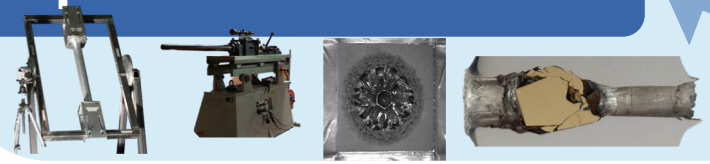


Numerical and analytical modelling / algorithm

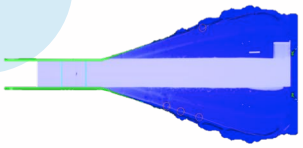




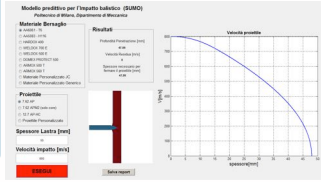
Experimental Tests



Validation of the modelling / algorithm approaches



Definition of predictive models/methods
Design optimisation
Structural Health Monitoring (monitoring, diagnosis and prognosis)
Fitness for purpose



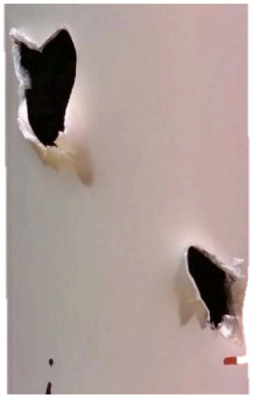
Outlook of the framework: a fit for purpose / multidisciplinary technology platform

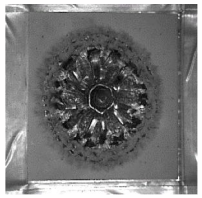
Experimental Tests

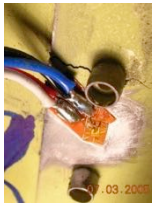
Test on **coupon and small specimens** to determine mechanical behavior

Metal Composite and Ceramic: plasticity, damage - Access to fully equipped materials lab including: quasi-static tension, compression and torsion testing at different temperatures, hardness measurements, fatigue testing, optical microscopy, scanning electron microscopes with coupled EDS and EBSD probes, X-ray diffractometer, CT scan, HIP - test under quality system

Test on **subsystem** also in presence of extreme loading condition





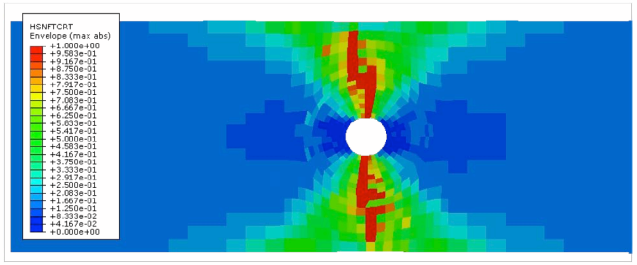


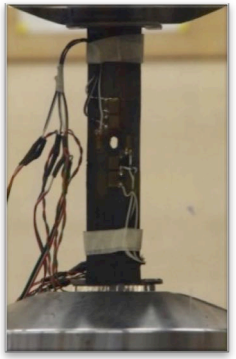
Test on **full-scale components** even for certification purpose

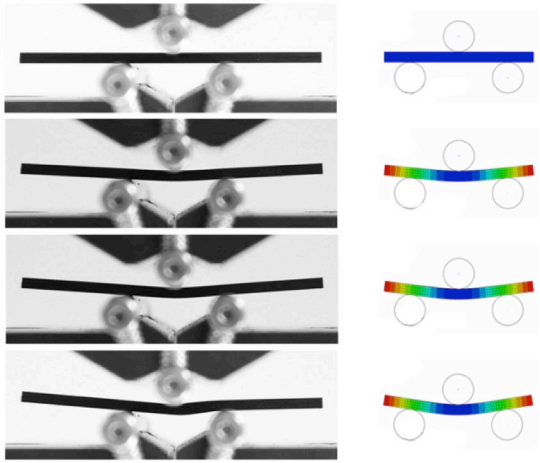
Outlook of the framework: a fit for purpose / multidisciplinary technology platform

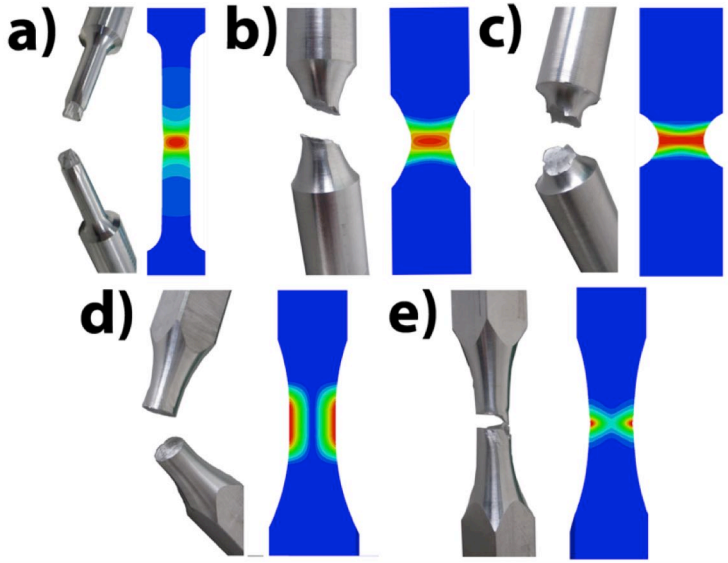
Material calibration

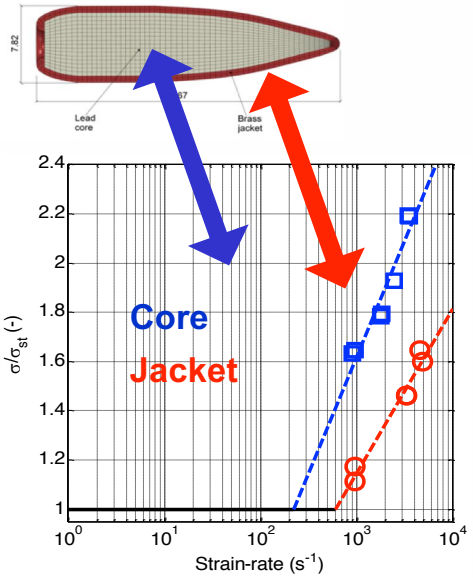
- Material behaviour: focus on **metal - ceramic – composite**
- Inverse methods for **calibration** of mechanical properties
- Definition of **constitutive models** able to describe high plasticity, ductile/brittle failure, strain rate, delamination, etc
- Creation of ad-hoc routine





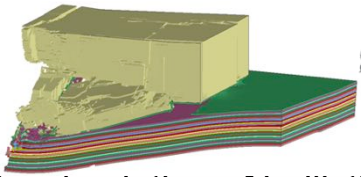


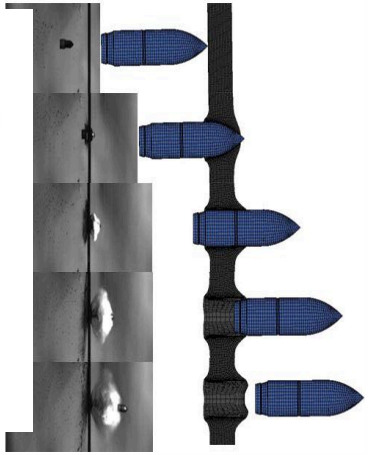




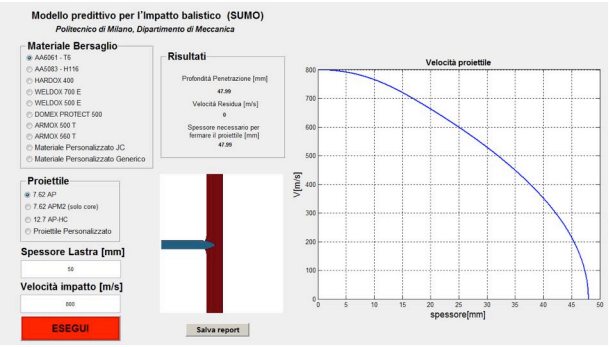
Outlook of the framework: a fit for purpose / multidisciplinary technology platform

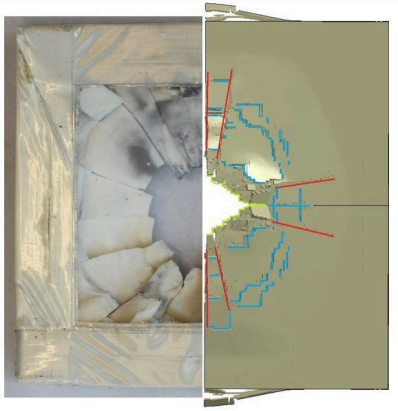
Modelling

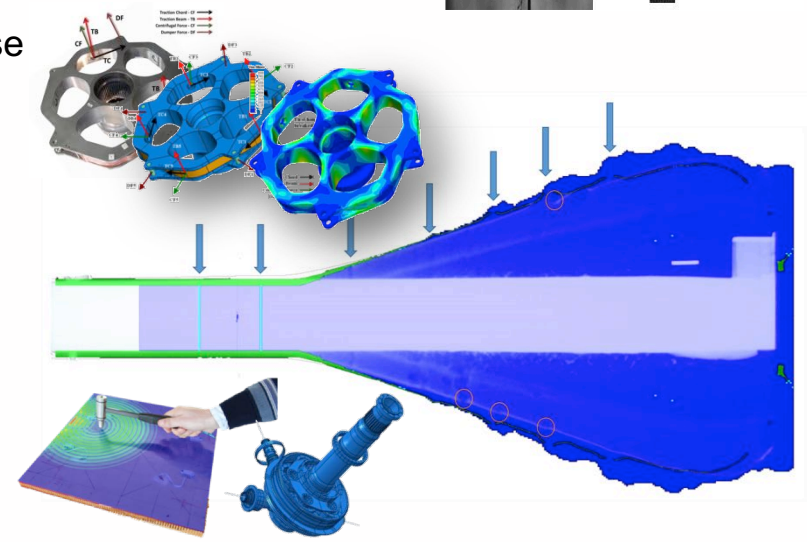




- Creation of **analytical models** for simulation of ballistic impact against Metal (cavity expansion) – Composites (energy balance and wave theory) – Ceramic (modified Bernoulli equation)
- Creation of **numerical models** (ABAQUS – Ls-Dyna)
  - ✓ large plasticity, high strain rate, high temperature and pressure, fracture and damage criteria, large fragmentation, delamination.
  - ✓ Lagrangian, ALE, SPH, perydinamics and in general expertise in mesh-free methods and coupling with lagrangian element.



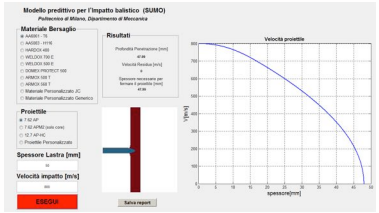




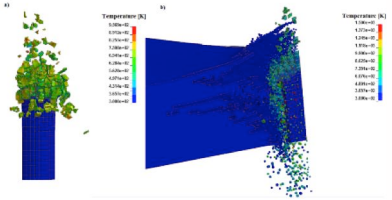
Outlook of the framework: a fit for purpose / multidisciplinary technology platform

Definition of predictive methods

Numerical and analytical modelling



Why are so important

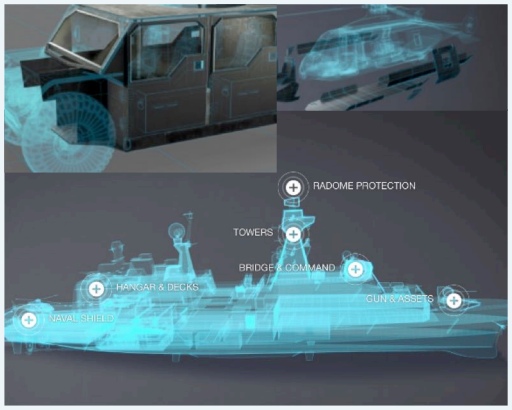


- Better **understanding of the physical phenomena** involved
- Better understanding of **effects of several parameters** (in highly non-linear environment)
- Possibility to perform **“virtual test”** when experimental approach is **unsafe and/or unfeasible**
- Reduction of the number of the experimental tests (time and costs reduction) and **better design of testing activities**
- Possibility to perform **optimization process and fitness for purpose** approach

The role of "Virtual test" in the design and assessment of innovative products aimed to defense system

Requirement:

Performances as a function of treats and operational conditions



Design and optimization

- Experience (*not always reliable*)
- Experimental testing (*time consuming and costly*)

Virtual test

- Predictive models
- Virtual tests
- **Reducing costs / uncertainties / development time**
- **Increasing fitness for purposes**
- **Optimization**

Validation

Certification, assessment of the finesses for purpose

???

Possible unfitting that require another interaction with the design phase

More direct progress toward a fitted and reliable product

Final product

Outlook of the research activities: from actual requirements to R&D

Efforts have been spent in this field starting from three actual tasks:

- Assessment of the residual life and strength of helicopter T/R shafts after ballistic perforation (thin walled structure – aeronautical components): ***Ballistic damage tolerance tests on the NH90-T129A tail rotor shafts***

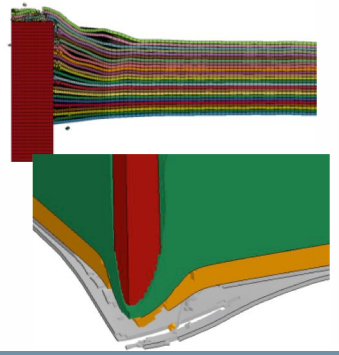
LEONARDO

- Evaluation of an optimized procedure for prediction of low caliber bullet penetration in thick armor plate (ground vehicle, civil structure, etc.): ***SUMO***

SUMO - P.N.R.M. (Italian National Project for Military Research), completed in 2013:
SvilUppo di un MOdello predittivo per l'impatto balistico
Development of a predictive model for ballistic impact

MINISTERO DELLA DIFESA

- Investigation in modeling low caliber bullet penetration in multilayer armor (composite – ceramic - metal): **SUMO 2**



SUMO2. P.N.R.M. (Italian National Project for Military Research), work in progress:
SvilUppo di una Metodologia analitica, numerica e sperimentale per la progettazione di protezioni balistiche cOmposite multistrato.
Development of a predictive model for multilayer protection

Project: ISSA

European Defence Agency Tendering procedure, Ad Hoc Research & Technology Project, No B 1190 ESM2 GP "Integrated Simulation of Non-Linear Aero-Structural Phenomena Arising On Combat Aircraft In Transonic Flight", ISSA 2013-2016

EUROPEAN DEFENCE AGENCY

The scope of ISSA is to create an environment of validated linear and high-fidelity analytical methods and tools for the investigation of LCO, mainly focusing on fighter external store configurations flying in transonic conditions.

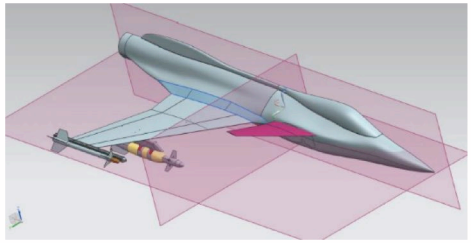
- Develop high-fidelity methods for the simulation of LCO, based on the coupling of CFD/CSM models that include aerodynamic and structural non-linearity;
- Develop methods for the linearization of the phenomenon and the application of linear tools currently in use to industry, corrected using the results of high-fidelity simulation;
- Upgrade an existing aeroelastic wind tunnel model with the addition of parametric pylon-store systems, designed to investigate LCO phenomena in the wind tunnel;

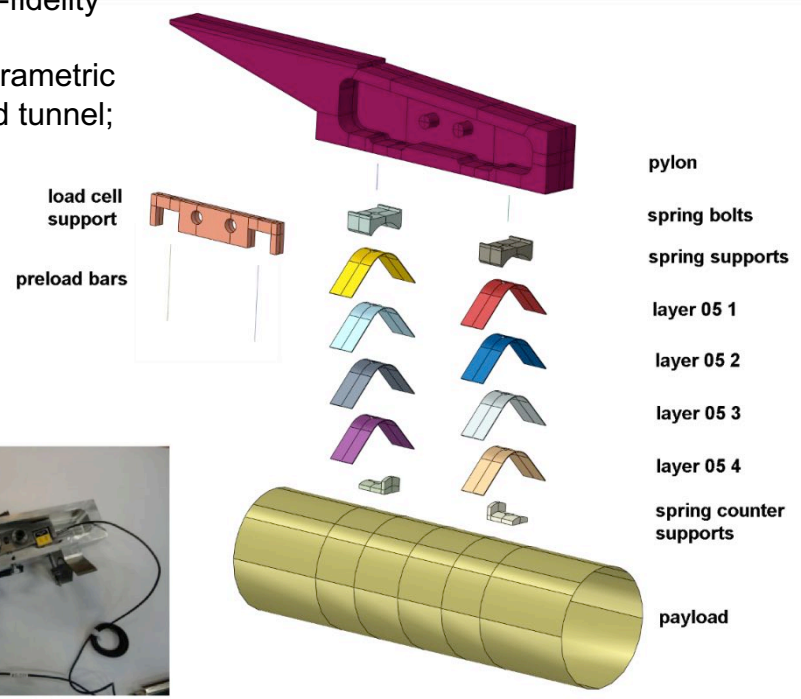
POLIMI contribution is mainly related to non-linear structural analyses and linearization methodology

LEONARDO

KTH VETENSKAP OCH KONST

SAAB



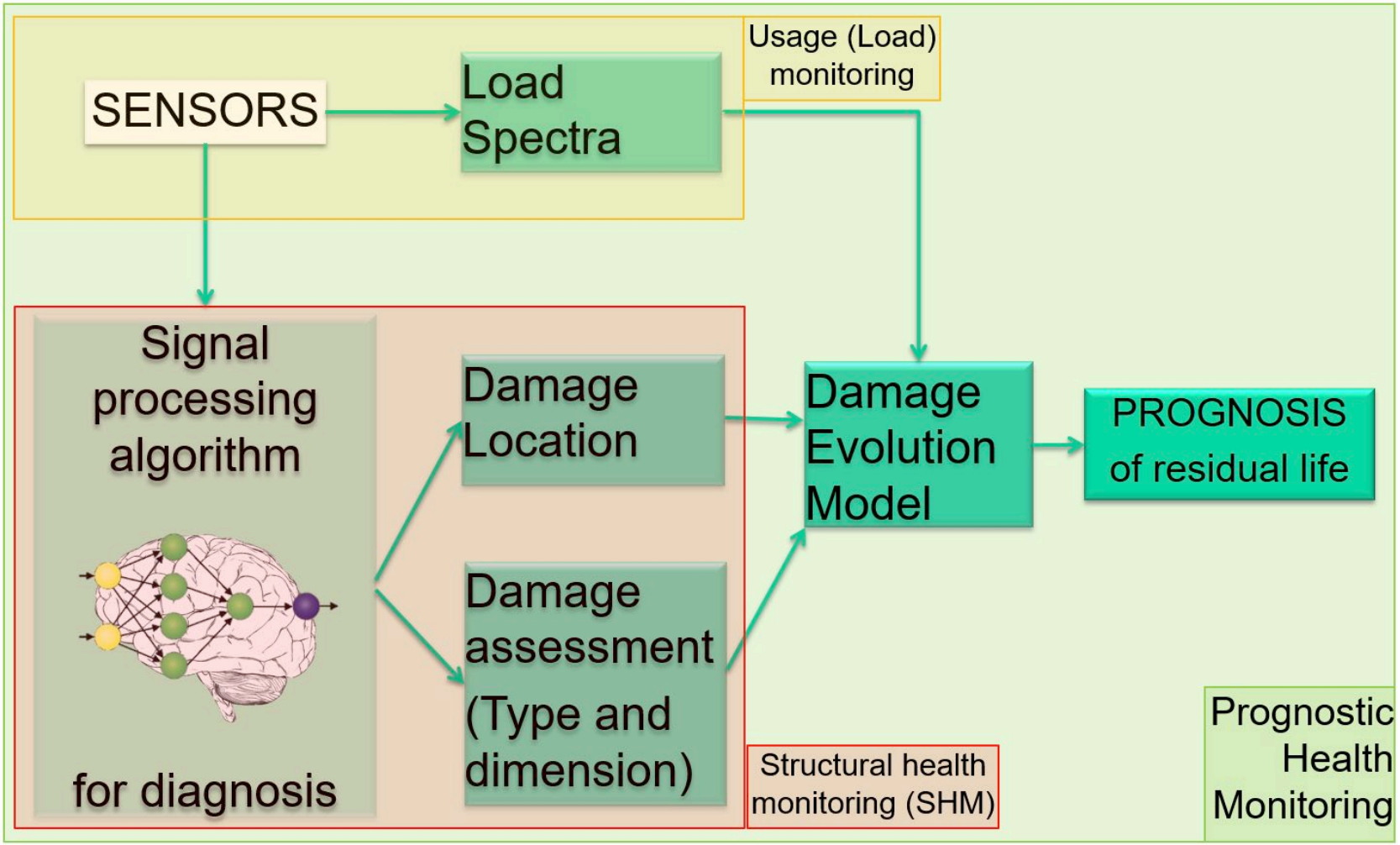


SIGMALab: research Areas

Model-based Structural Health and Usage Monitoring (HUMS) and prognosis

- Investigation of different state of art sensor technologies for SHM
- Numerical and analytical modelling for SHM system training
- Machine learning and pattern recognition for diagnosis
- Bayesian filters and Monte-Carlo methods for prognosis
- Experimental SHM verification and performance qualification

What HUMS and Prognosis means?

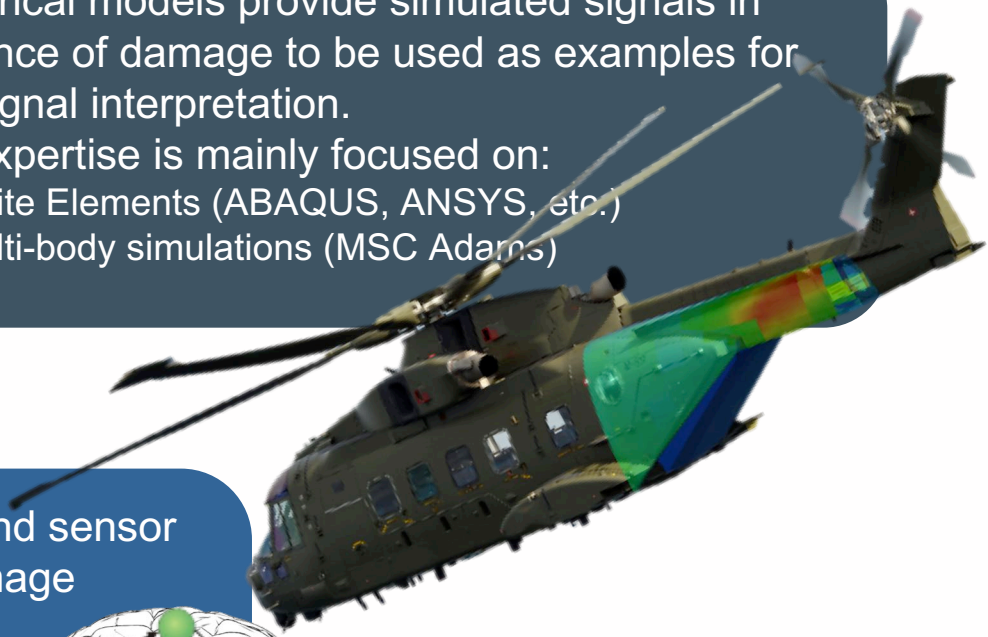


What do we need?

Sensors provide a signal dependent on damage that has to be interpreted.

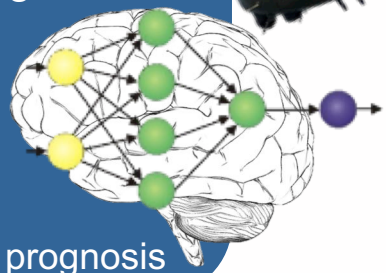
Numerical models provide simulated signals in presence of damage to be used as examples for real signal interpretation.
Our expertise is mainly focused on:

- Finite Elements (ABAQUS, ANSYS, etc.)
- Multi-body simulations (MSC Adams)



Signal processing tools combine numerical and sensor data to provide feature classification and damage diagnosis. Our expertise is focused on:

- Feature extraction
- Supervised machine learning for diagnosis
- Statistical model-based filtering for diagnosis and prognosis



Outlook of the research activities: monitoring causes and consequences of damage

Load monitoring systems

Which is the actual structural ageing, under operative loads?
Did any extreeme event occur?

- Strain at virtual nodes
- External load identification
- Impact position, energy and damage

Structural health monitoring (SHM) systems

Is there any damage propagating?

- Damage detection
- Damage position
- Damage length

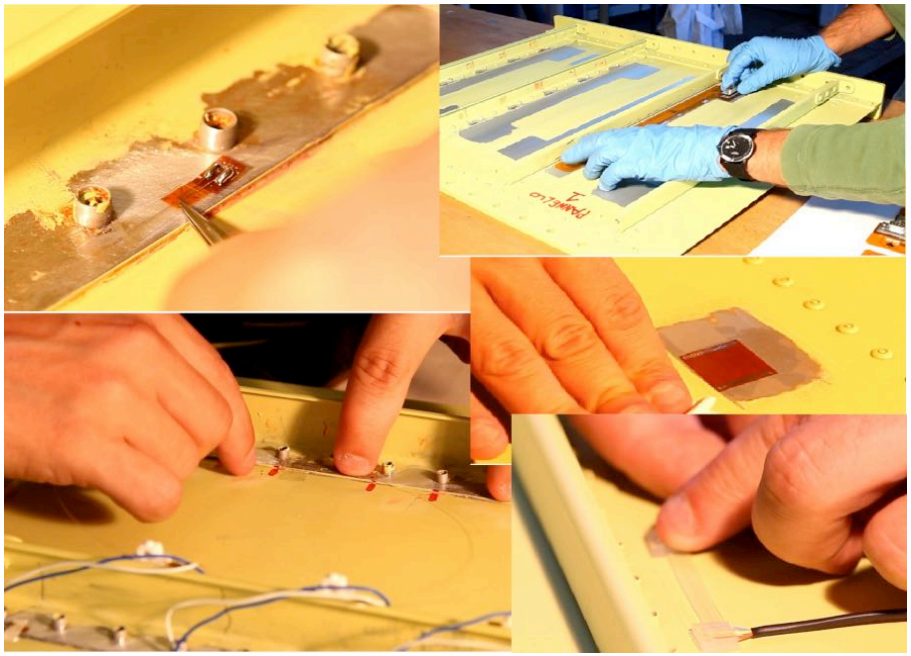
Prognostics and Health Management (PHM) systems

Which is the expected residual life?

- Stochastic residual life definition
- Uncertainty updating

The SENSORS:
Network optimisation for structural anomaly detection

Various state of the art sensor technologies have been tested for HUMS, including:



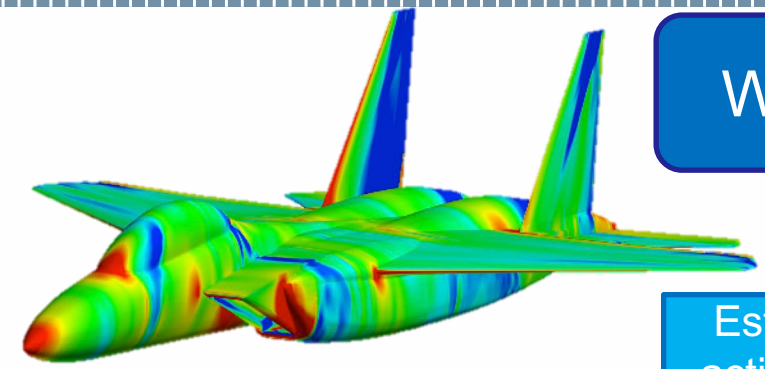
Electrical sensors:

- strain gauges
- crack gauges
- piezoelectric actuators and sensors
- acoustic emission sensors, etc.
- Embedded Carbon-Nanotubes

Non-electrical sensors:

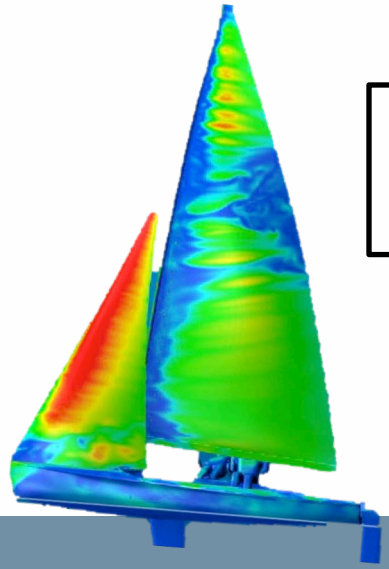
- Optical fibre Bragg grating
- Interferometric fiber optic sensor (Michelson)
- Comparative vacuum monitoring, etc.

Load monitoring

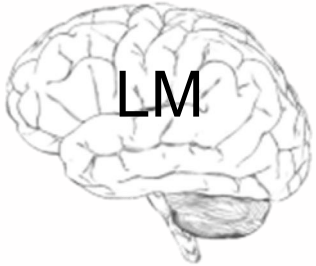


What is LM?

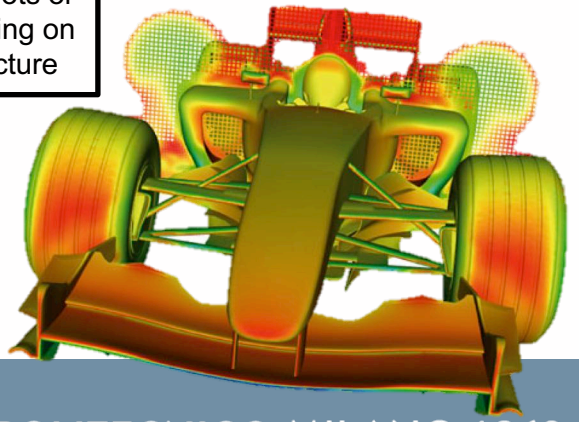
Estimation of loads acting on a structure and load extrapolation to the entire structure



Available data (e.g. strains, accelerations etc.)

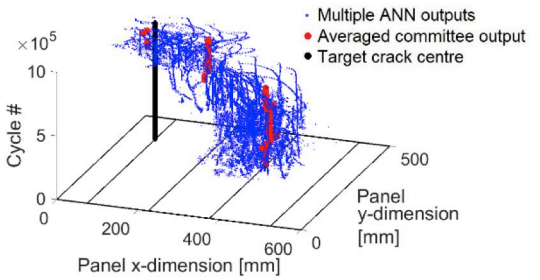


Stresses at critical spots or loads acting on the structure



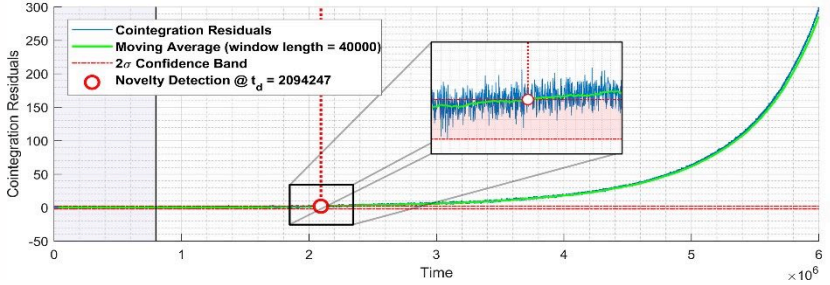
Damage diagnosis

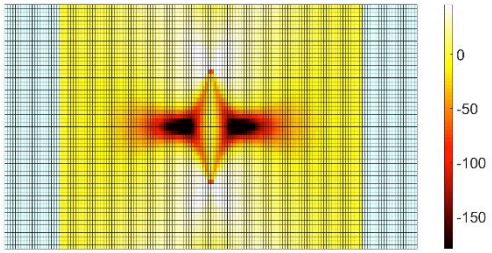
Machine learning for fast and real-time SURROGATE modelling



Data Normalisation for removal of environmental and operational influences

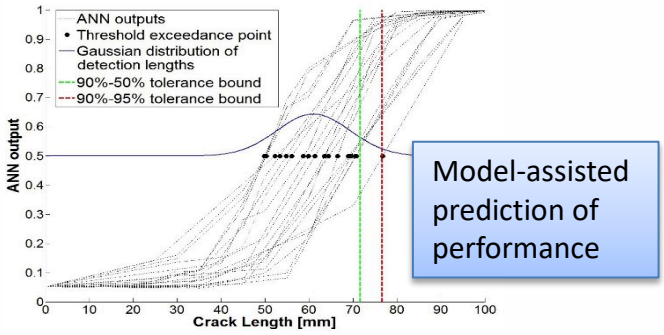
- Regression
- Data Projection
- Cointegration
- iFEM





Enhanced model-based framework, leveraging on analytical and numerical modeling for:

(i) Sensitivity analysis and feature extraction
(ii) Sensor network design
(iii) Diagnostic algorithm training
(iv) Surrogate model training
(v) Model-assisted performance qualification



Damage prognosis
Problem statement

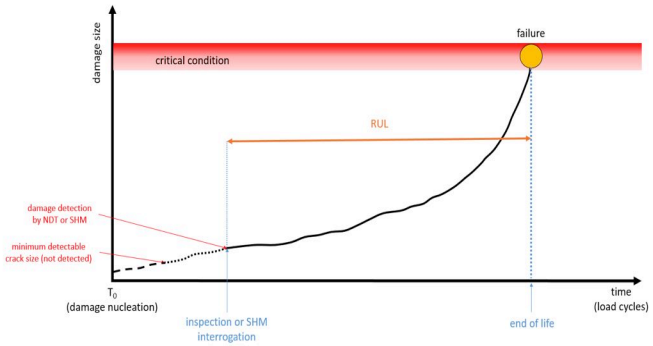
Performing the **prognosis** of a system subject to degradation means calculating the **residual life** according to all the observations gained from:

- Prior experience
- Actual observations of the damage available in real-time by a SHM system
- Actual observations of the loads measured by the load monitoring system

This has to be done in a probabilistic way. **Sequential Monte-Carlo** algorithms allow for the definition of a stochastic framework in which it is possible to:

- Refine the uncertainty on the measure of the damage
- Refine the uncertainty on the parameters governing the damage evolution
- Decide which is the best model to describe the system dynamics
- Update the residual life probability density function

The algorithm works in REAL-TIME



A solution: Sequential Monte-Carlo (Particle Filter)

State Estimation

Filtering of the diagnostic output dispersion

Model Parameter Estimation

Filtering of the model parameter distribution

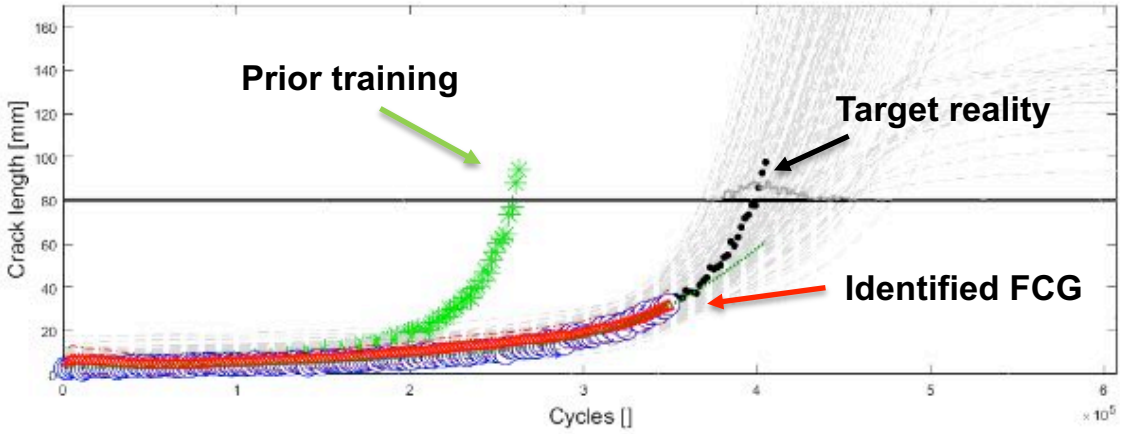
Adapt the filtered output to a generic load spectrum

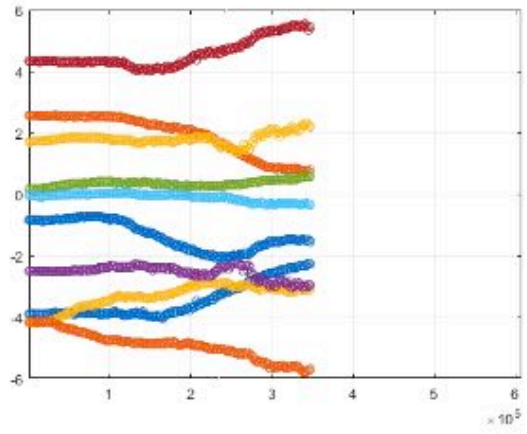
Model Identification

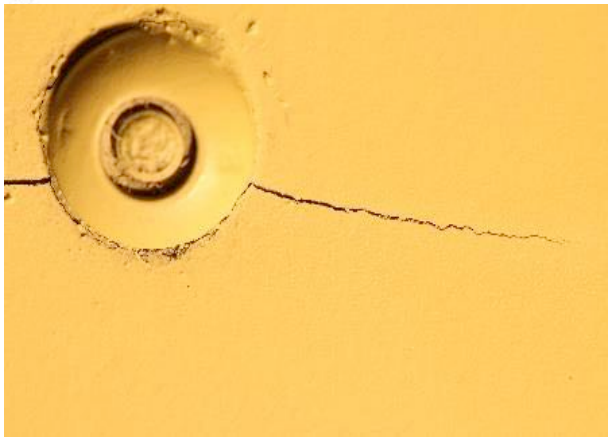
Which model better predicts our sequential data?

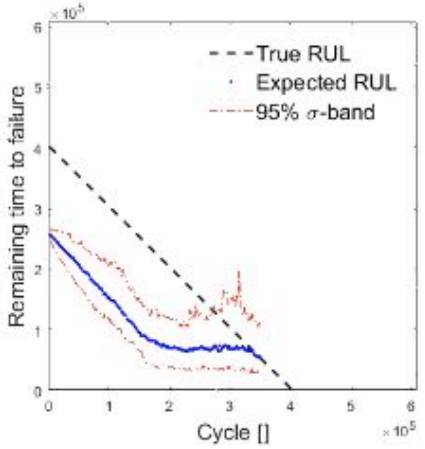
PROGNOSIS

Damage prognosis
Example results in Fatigue Crack growth identification





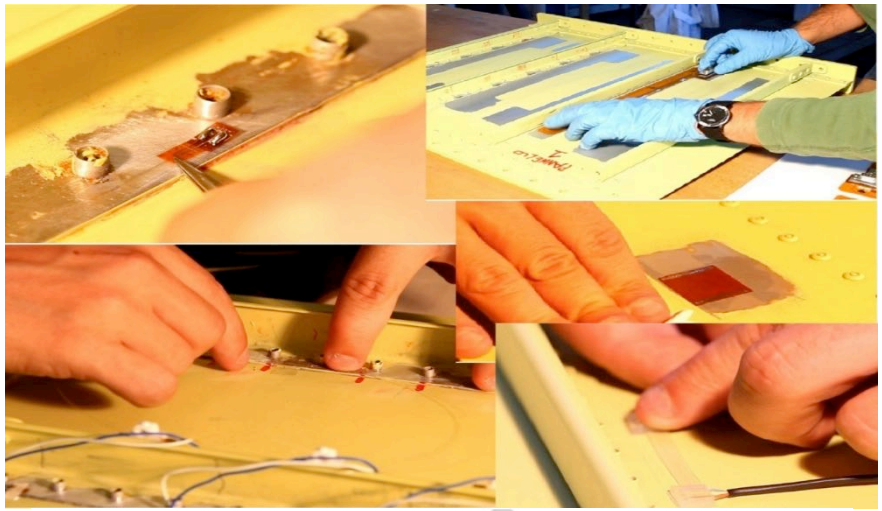


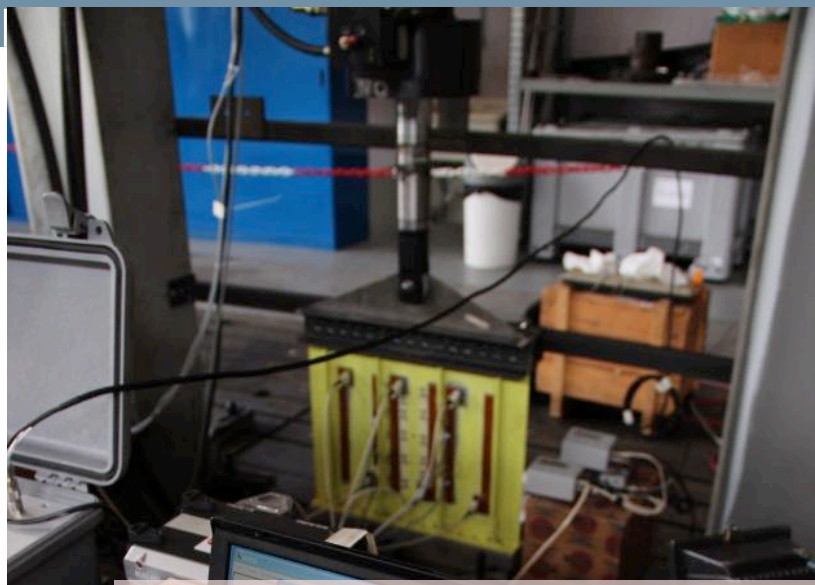


Project: HECTOR

European Defence Agency Joint Investment Programme on Innovative Concepts and Emerging Technologies (JIP-ICET), Call N. 1, Ref. A-0779-RT-GC: "Monitoring and control", "HElicopter fuselage Crack moniToring and prognosis through on-board sensOR" - HECTOR, 2009-2011

SHM methodology to monitor on-line the damage accumulation and propagation during service (diagnosis) and to evaluate the time inspections and remaining life (prognosis) in helicopter frames



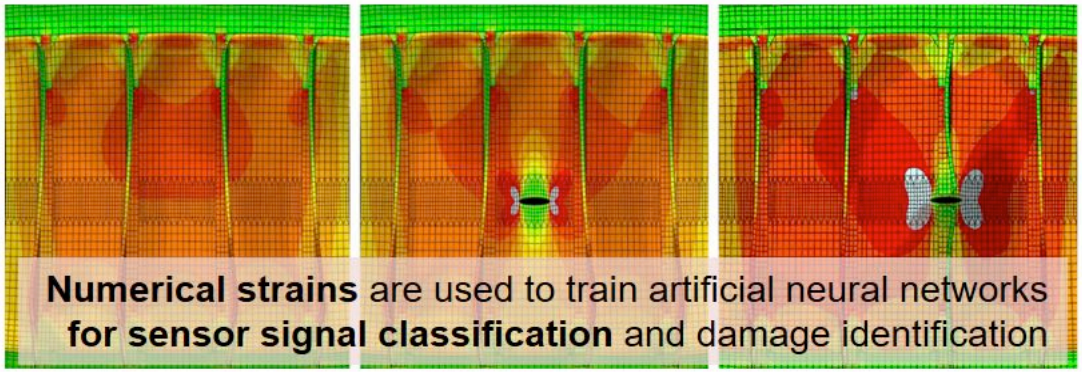


Fatigue tests of pre-cracked metallic panels representative of rear helicopter fuselage for **Structural Health Monitoring**: Complete test design and set-up, design and manufacturing of the test rig, assessment of several sensors technologies (strain gauges, fiber Bragg gratings, CVM, crack gauges, PZT smart layer) for **automated damage identification**

Project: HECTOR

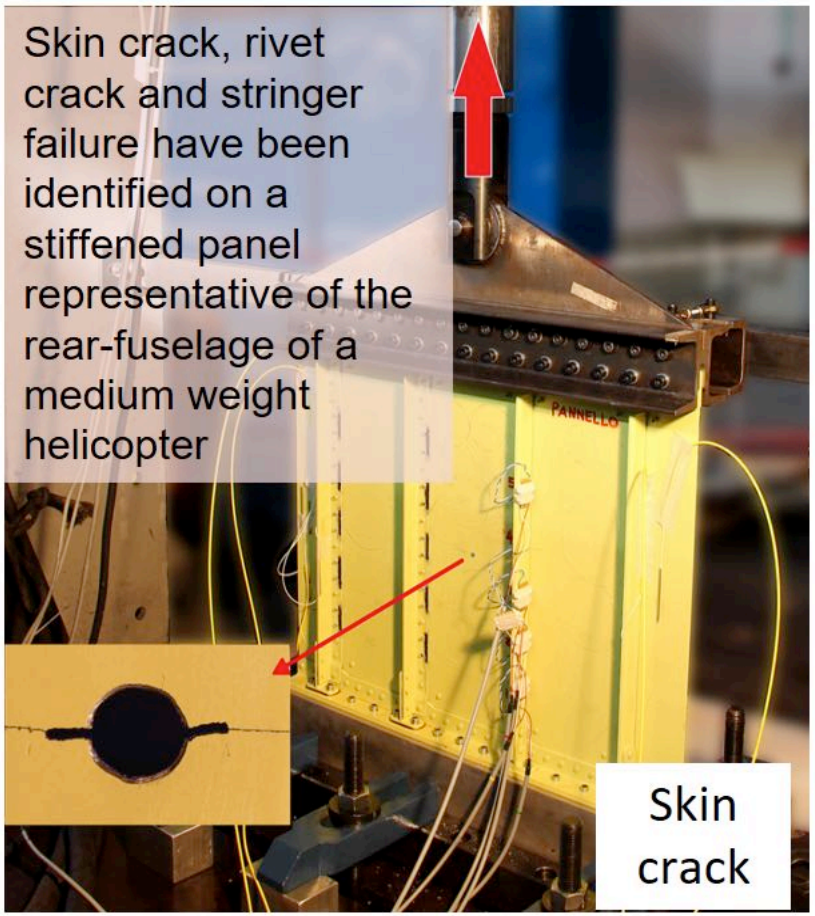
European Defence Agency Joint Investment Programme on Innovative Concepts and Emerging Technologies (JIP-ICET), Call N. 1, Ref. A-0779-RT-GC: "Monitoring and control", "HElicopter fuselage Crack moniToring and prognosis through on-board sensOR" - HECTOR, 2009-2011

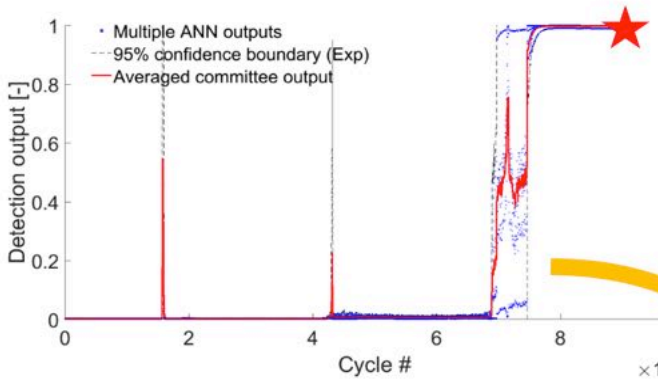
Diagnostic system based on strain field measures (FBGs) for damage identification, localisation and quantification



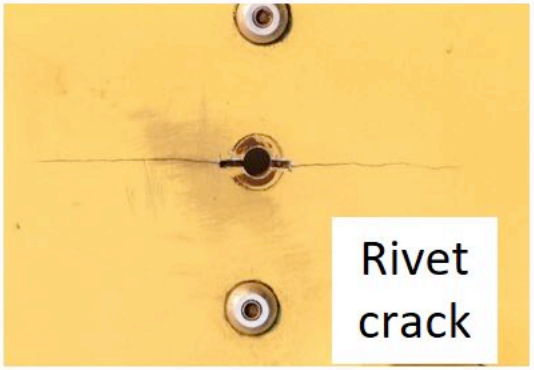
Numerical strains are used to train artificial neural networks **for sensor signal classification** and damage identification

Skin crack, rivet crack and stringer failure have been identified on a stiffened panel representative of the rear-fuselage of a medium weight helicopter





Real unexpected stringer failure detected and localized 200.000 cycles before failure



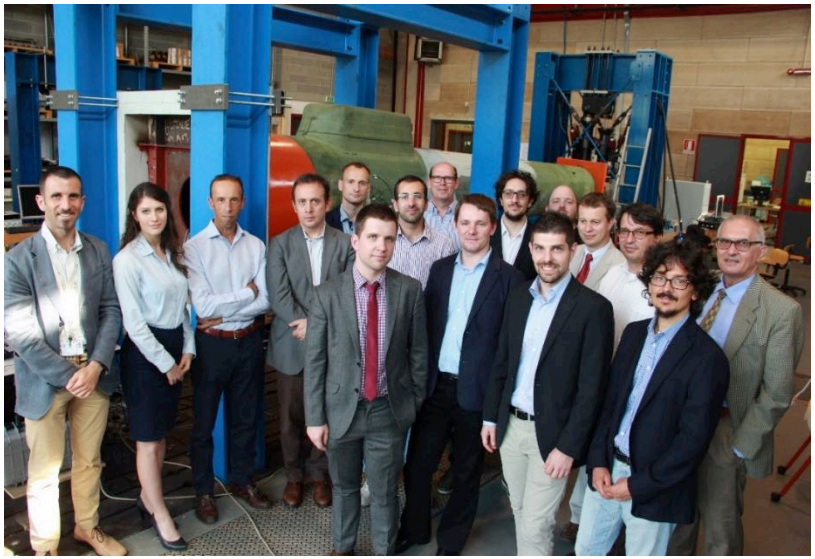
Project: ASTYANAX

European Defence Agency Tendering procedure, Ad Hoc Research & Technology Project, No B 1288 ESM2 GP, "Aircraft fuSelage crack moniToring sYstem And progNosis through on-boArd eXpert sensor network" - ASTYANAX, 2012-2015

ASTYANAX project pushes the HECTOR SHM methodology to a higher TRL by its application to relevant full-scale experimental tests:

- Helicopter HARSH LANDING assessment
- Real-time automated diagnosis of a helicopter tail-boom
- Cost-Benefit analysis of the SHM implementation on a realistic helicopter fleet

Military Aviation Works Nr.1



Project: ASTYANAX

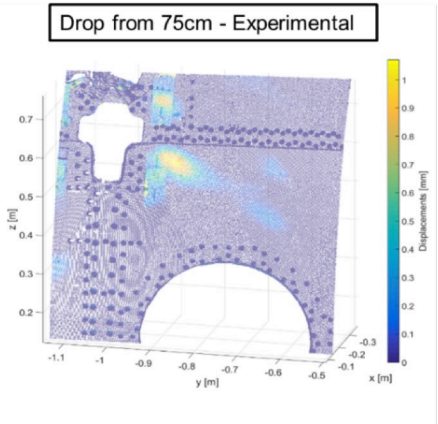
European Defence Agency Tendering procedure, Ad Hoc Research & Technology Project, No B 1288 ESM2 GP, "Aircraft fuSelage crack moniToring sYstem And progNosis through on-boArd eXpert sensor network" - ASTYANAX, 2012-2015

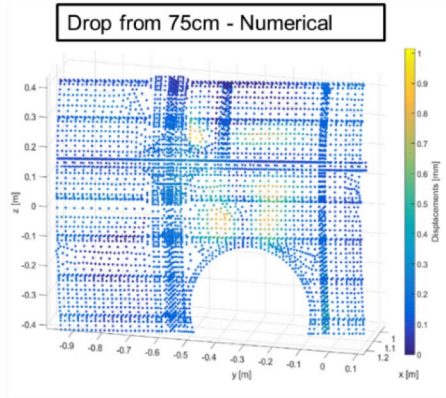
HARSH LANDING assessment. Numerical models are used:

(i) to predict the signal features for automated harsh landing classification

(ii) to predict damage as a function of the landing parameters

- Participation to design and execution of drop tests
- Sensor network design and acquisition
- Numerical modelling
- Algorithm for automated harsh landing classification





Project: ASTYANAX

European Defence Agency Tendering procedure, Ad Hoc Research & Technology Project, No B 1288 ESM2 GP, "Aircraft fuSelage crack moniToring sYstem And progNosis through on-boArd eXpert sensor network" - ASTYANAX, 2012-2015

Real-time automated diagnosis of a helicopter tail-boom.

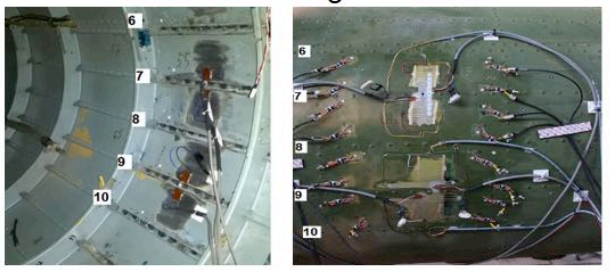
(i) FULL-SCALE design and setup of fatigue test on a Mil-Mi-17 helicopter tail-boom.

(ii) Sensor network design, installation and acquisition

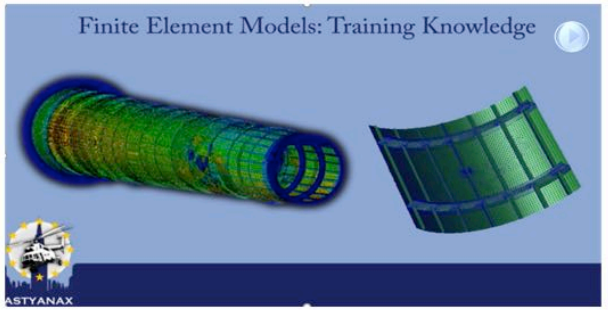
(iii) Qualification of SHM system performances (minimum detectable crack length – ARP6461)

(iv) Cost-benefit analysis

Sensing



Simulation



Test

Project: SAMAS

European Defence Agency Tendering procedure, Ad Hoc Research & Technology Project, "SHM Application to UnMAnned Aircraft Systems ", SAMAS 2017-2020

The focus is on composite structures

The main streams of activity are:

- Numerically-enhanced load monitoring system for real time estimation of fatigue consumption
- Impact monitoring system for impact assessment (detection, localisation and impact energy assessment) and model-based damage estimation.
- SHM guidelines for SHM qualification, standardization and certification
- Cost Benefit Analysis and Life Cycle Costs
- Application to ground and flight platform (RPAS)

HECTOR (Completed December 2011):
HElicopter fuselage **C**rack moni**T**oring system and prognosis through on-board sens**OR** network — TRL 3-4

ASTYANAX (Completed December 2015):
Aircraft fu**S**elage crack moni**T**oring s**Y**stem **A**nd prog**N**osis through on-bo**A**rd e**X**pert sensor network — TRL 4-5

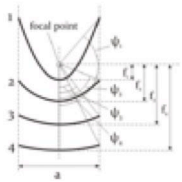
SAMAS (Start December 2017):
SHM **A**pplication to un**M**anned **A**ircraft **S**ystems — TRL 5-6

Design of an innovative Solar Through

SOLAR THROUGH DESIGN AND OPTIMIZATION 1 of 2

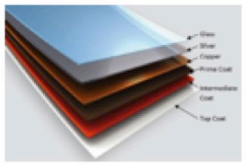
DESIGN AND **TECNICAL SOLUTIONS**
(Manufacturing costs, materials and design solutions)

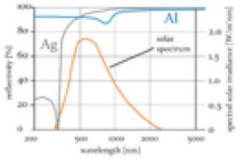
Dimensions



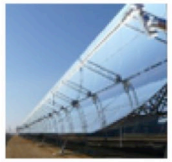
Design solutions and materials

Mirrors



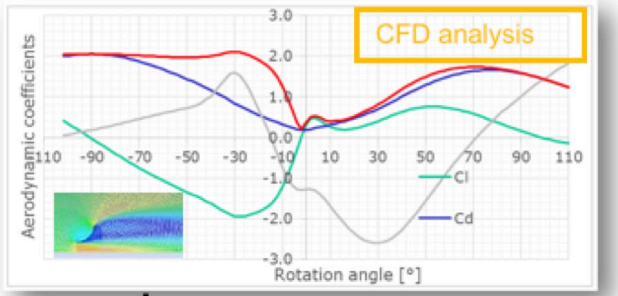


Receiver



FINAL OPTIMAZED DESIGN

LOADS (**CFD**) and **EFFICIENCY CALCULATION**
under work loads (**FE and analytical**)

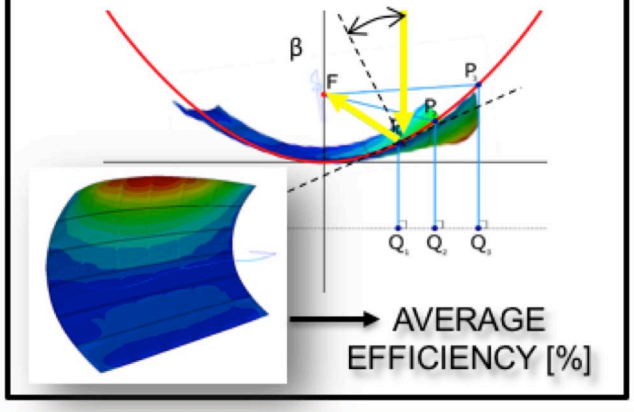


Pressure field

High speed wind and low speed wind pressure field

Low speed wind pressure field

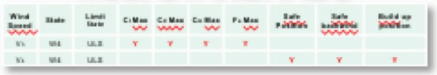
FE model – mirror deformation under normal operational speed wind.



AVERAGE EFFICIENCY [%]

STRUCTURAL OPTIMIZATION AND **VERIFICATION: life prediction.**

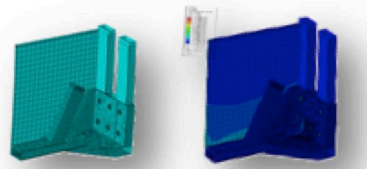
Meet STANDARDS



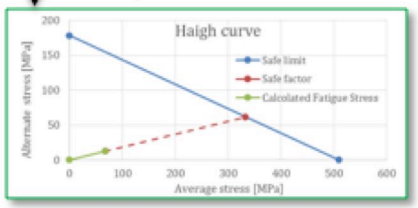
Y = verified

High speed wind stress field

FE model: stress calculation under ultimate loads (high speed wind) and operational loads (low speed wind) for Fatigue analysis.



Low speed wind stress field



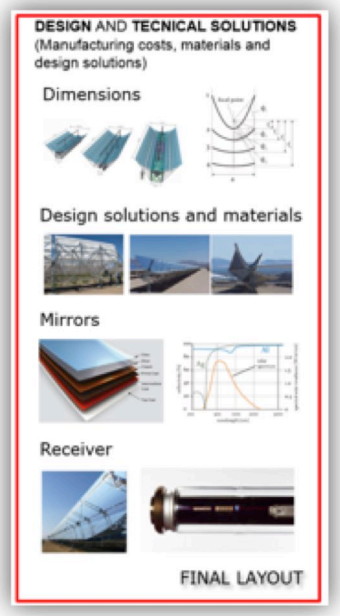
Fatigue analysis:
LIFE PREDICTION [Years]

Costs assessment for a **single trough**: **weight, manufacturing, work life** and **efficiency**

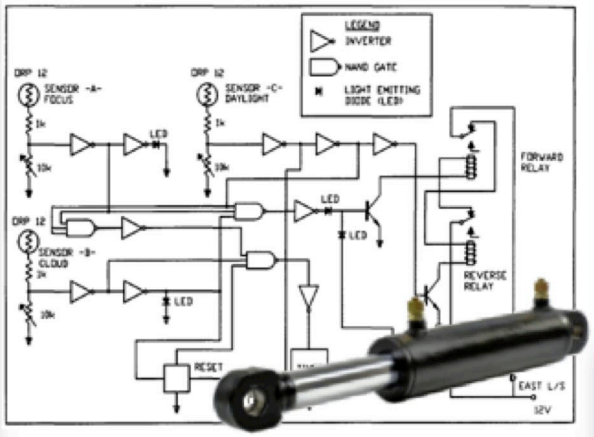
Design of an innovative Solar Through

SOLAR THROUGH DESIGN AND OPTIMIZATION 2 of 2

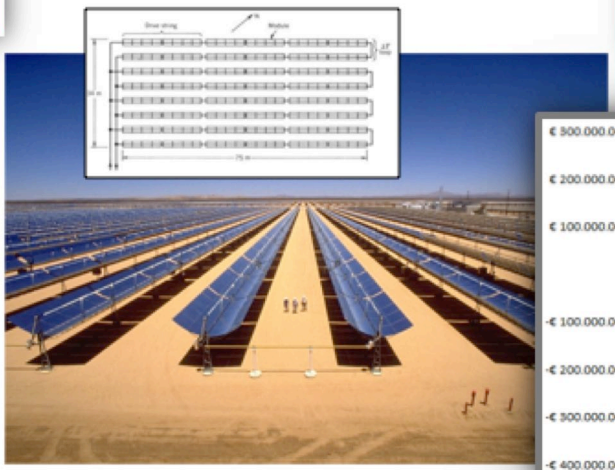
FINAL DESIGN



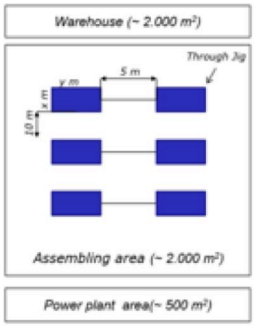
ACTUATION AND HYDRAULIC SYSTEM



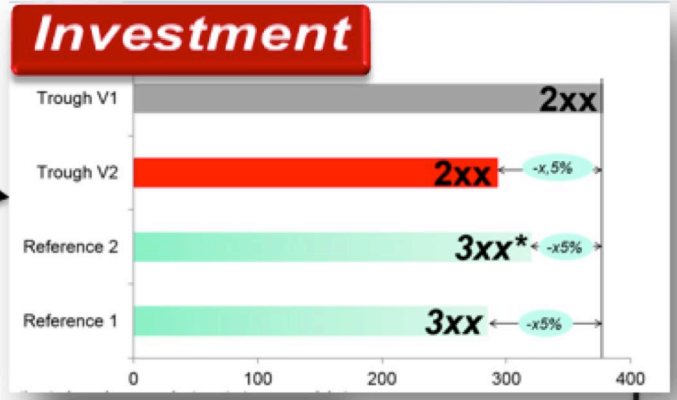
SOLAR FIELD DESIGN

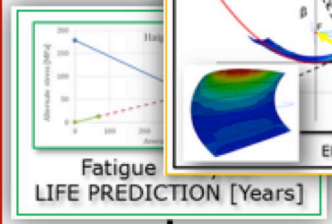


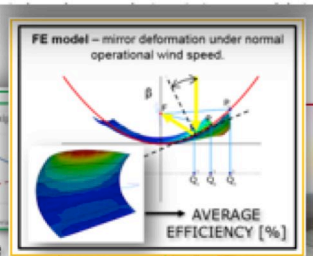
WEREHOUSE OPTIMIZATION

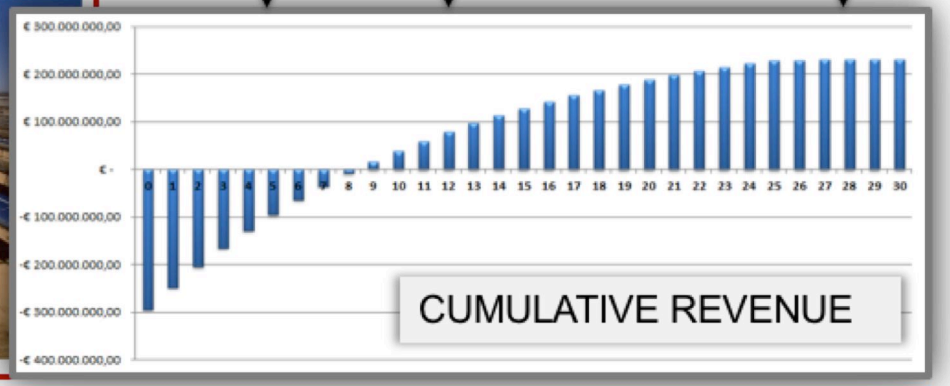


Investment









Costs assessment for the **through field**: **final revenue**

Relevant projects submitted for evaluation

P.N.R.M. (Italian National Project for Military Research),

Consortium: Italy (Politecnico di Milano)

OPTY-V

Ottimizzazione di una ProTezione "underbodY" per Veicoli nei confronti di una carica sepolta (OPTY_V)

Improve and optimize survivability in under-body blast attack by means of advanced numerical modeling

VULNUS

Analisi della VULNerabilità di costrUzioni in calceStruzzo soggetti ad impatti ed esplosioni – VULNUS

Define a methodological approach for survivability analysis of concrete structure subjected to impact and explosion

Relevant projects submitted for evaluation

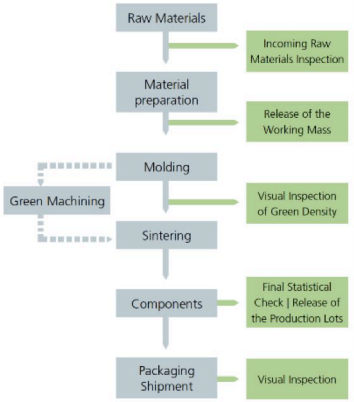
P.N.R.M. (Italian National Project for Military Research),

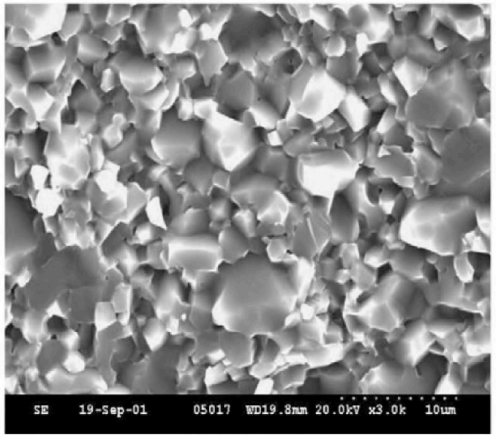
Consortium: Italy (Politecnico di Milano – Bitossi)

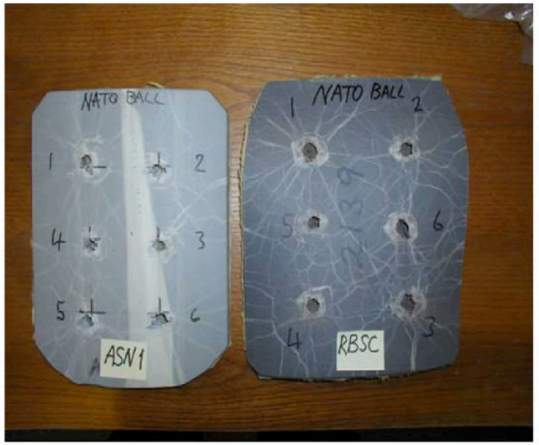
AIDENTITI

IdentificAzIone una metoDologia Efficace per la correlazione del processo tecNologico, proprieTà fisiche e mIcrostrutturali e prestazione balisTica di piastrelle ceramIche

Identification of an effective methods in order to correlate technological process, physical and microstructural properties and ballistic performance of ceramic tiles







Relevant projects submitted for evaluation

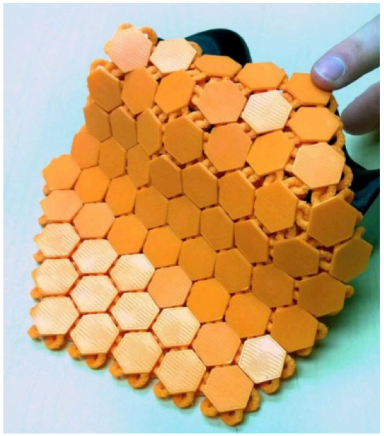
PADR Preparatory action for defense research

Role: subcontractor in the consortium

EUROPEAN COMMISSION

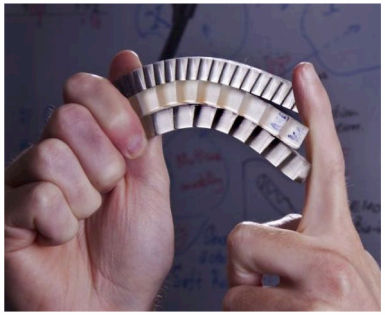
INCA

A project for the development of an innovative personal protection aimed to explore the best technologies in "soft armour", "hard plate" and "CBRN"



ROLE of POLIMI

POLIMI will use his expertise in modelling terminal ballistic event to create analytical and numerical models to investigate on the behaviour of several solutions against high speed bullets. Focus on the reproduction of the back-face signature of bullets and fragments – Optimization



SIGMALab

Team Leader

Marco GIGLIO
Full Professor, Deputy Director MECC
Politecnico di Milano
Dipartimento di Meccanica
(Department of Mechanical Engineering)
Milano Bovisa - Via La Masa 1
Building B22
20156 Milano - ITALY
Tel: + 39 02 2399 8234
Fax: + 39 02 2399 8202
Tel secretary: + 39 02 2399 8212
e-mail: marco.giglio@polimi.it
Skype: marco.giglio1
web: www.mecc.polimi.it

The material in this presentation has been prepared by SIGMALab team and is general background information about SIGMALab's activities and expertise current as at the date of this presentation. This information is given in summary form and does not purport to be complete. SIGMALab retains all intellectual properties associated with the presentation

Research Team

Andrea MANES Ph.D.
Associate Professor, Scientific Manager
Programme head of Structural Integrity under Extreme Load
andrea.manes@polimi.it
Tel: + 39 02 2399 8630

Claudio SBARUFATTI Ph.D.
Research Fellow - Assistant Professor
Programme head of Structural Health Monitoring and Prognosis
claudio.sbarufatti@polimi.it
Tel: + 39 02 2399 8213

Francesco CADINI Ph.D.
Research Fellow - Assistant Professor
Reliability and statistical approaches for structural integrity
francesco.cadini@polimi.it
Tel: + 39 02 2399 6355

Massimo FOSSATI Ph.D.
Research Fellow

Mauro SALVETTI
Research Fellow

Demetrio CRISTIANI
Research Fellow

Alessio BELIGNI
Ph.D. graduate student

Stefano CARDAMONE
Ph.D. graduate student

Luca COLOMBO
Ph.D. graduate student

Riccardo SCAZZOSI
Ph.D. graduate student

Simone LOMBARDO
Ph.D. graduate student

Dayou MA
Ph.D. graduate student