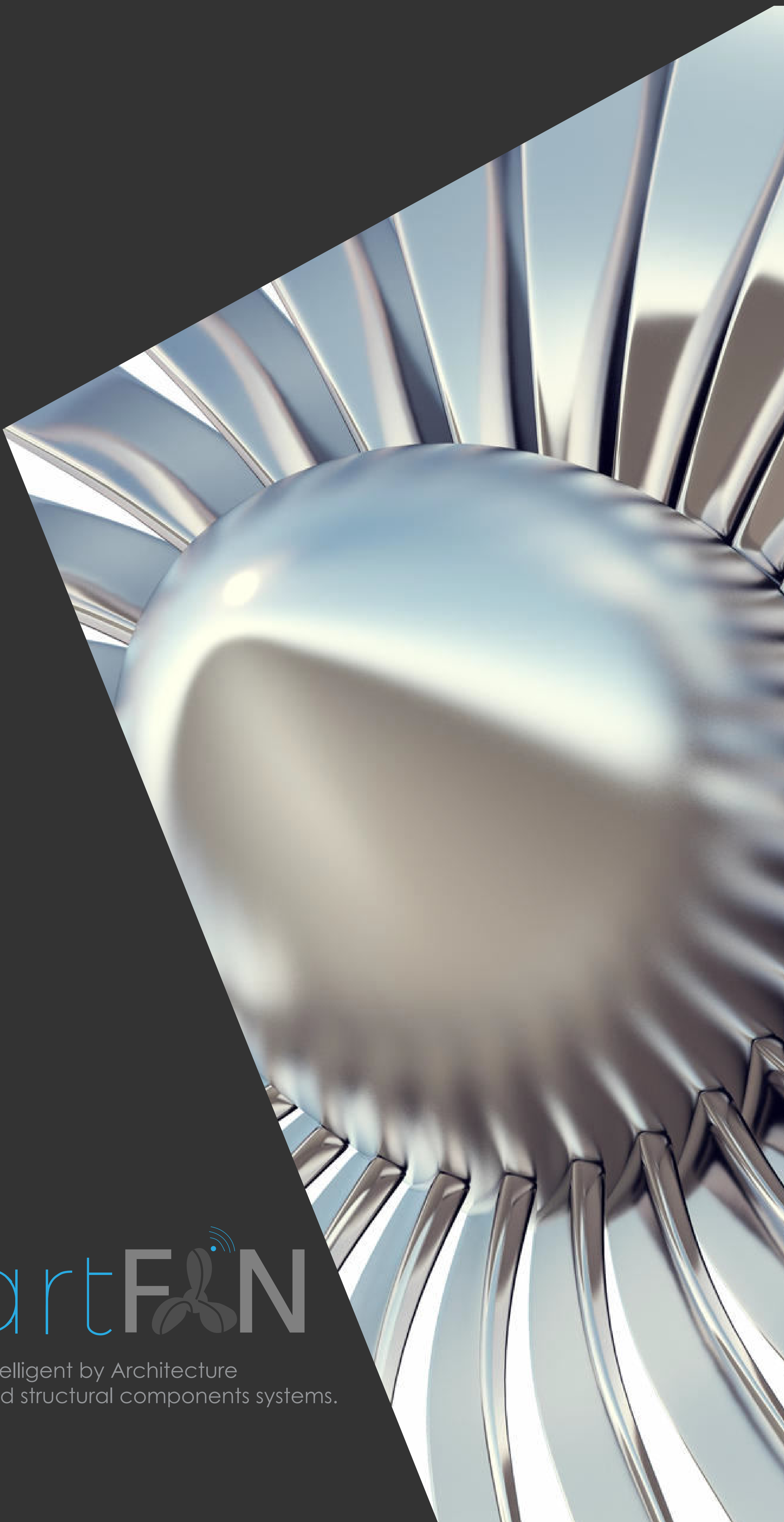
Volume 6



SmartFAN

Smart by Design and Intelligent by Architecture
for turbine blade fan and structural components systems.

Partners

1.National Technical University of Athens (**NTUA**)

2.Warrant Hub SRL (**WG**)

3.Association pour le Developpement de l'Enseignement et des Recherches Aupres des Universites, des Centres de Recherche et des Entreprises d'Aquitaine/CANOE Platform (**ADERA/CANOE**)

4.Dallara Automobili SPA (**DAL**)

5.Instituto Tecnologico De Aragon (**ITAINNOVA**)

6.Elica SPA (**ELICA**)

7.Foundation for Research and Technology Hellas (**FORTH**)

8.Innovation in Research & Engineering Solutions (**IRES**)

9.Techedge GMBH (**TECHEDGE**)

10.Inegi - Instituto de ciencia e Inovacao em Engenharia Mecanica e Engenharia Industrial (**INEGI**)

11.Politecnico di Torino (**POLITO**)

12.Thales SA (**TRT**)

13.Universita Degli Studi di Roma Tor Vergata (**UNITOV**)

14.The University of Birmingham (**UoB**)

15.3D NewTechnologies for medical and non-medical implementations (**BIOG3D**)

16.Open Source Management Limited (**OSM**)

17.Stratosphere (**STS**)

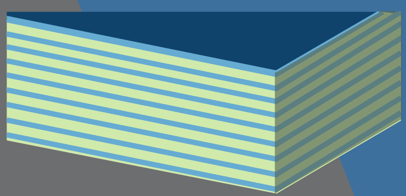
18.Lavrion Technological and Cultural Park (**NTUA /AMDC**)

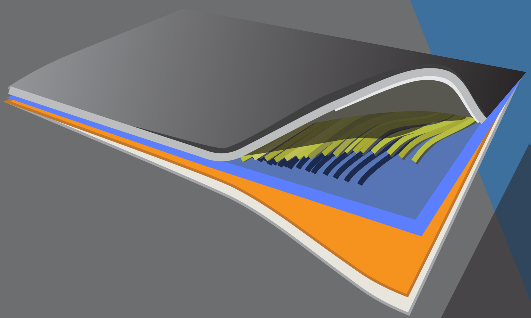
SmartFAN Framework

Smart by Design materials

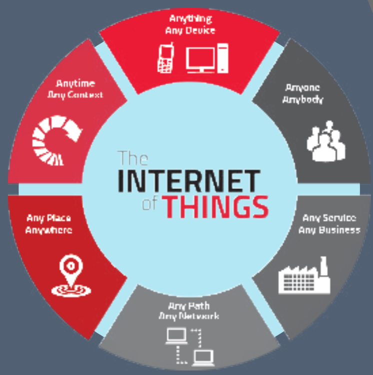
- Self-repair or self-healing materials
- Material for vibration suppression
- Lightweight composites
- Internal damage and process history
- Shape change
- Energy storage
- Functionally graded composite materials (FGCMs)

... now





SmartFAN L&G Concept



Intelligent by Architecture structures

- Advanced sensors (nanosensor technology)
- Damage detection
- Self-repair, Self-actuation
- Self-sensing, Self-morphing
- Magnetic functionality (for non-magnetic materials)
- Optical functionality
- Sound and vibration damping
- Thermal management in ICT

DALLARA

Smart Demos for Automotive Industry

In the frame of the Smartfan project, Dallara Automobili is developing an innovative front wing for the racing car sector.

The part was redesigned in an innovative way if compared with the traditional wings, with the aim of achieving the maximum product quality, in combination with a reduction of the production costs.

Prepreg carbon patches are initially preformed through a semi-automated process that involves the use of a vacuum bench. The preformed plies are subsequently placed into a mold and the final shape is obtained by compression molding. A specific tooling was designed to produce a part with an undercut geometry.

This process presents a number of innovations, including highly repeatable quality of the part, high strength and stiffness combined with lightweight.

In addition, the labor intensity required for the production of the part was significantly reduced. The time for the manufacturing of the part was reduced of more than 50%, with a resulting beneficial effect on the production costs of the part.

ELICA

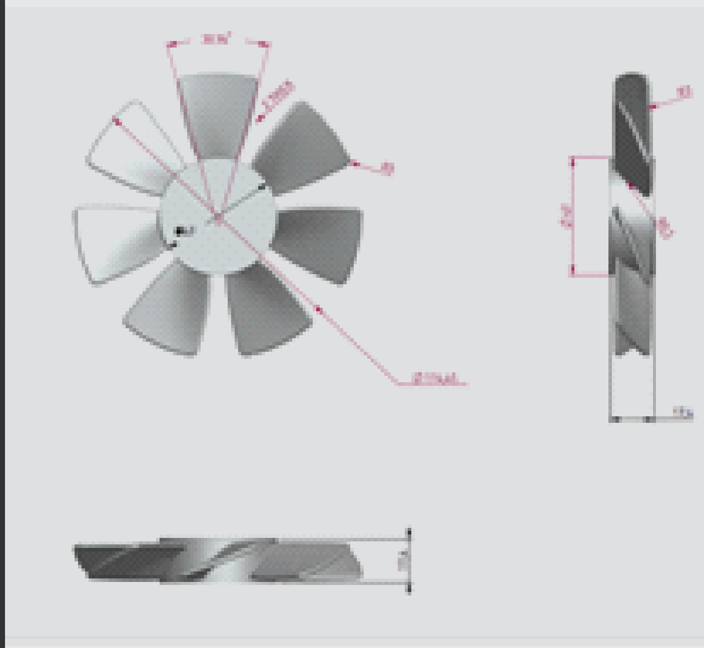
Smart Demos for Domestic Appliances sector

ELICAs efforts were focused on two main topics:

- Final design of the new impeller to be used in the new hood that is under development
- Final test to identify the proper raw material to be used to manufacture the new impeller

The impeller design obtained through CFD simulations has been reviewed and improved. A few adjustments have been made to fit the impeller in both application that ELC is developing.

Several raw materials have been supplied to CANOE for proper functionalization and then tested according to self-extinguish requirements. Finally, the material to be used for demonstrator has been identified - 5VAPPHO compounded with CNTs by CANOE fulfill all requirements.



BIOG3D

Development of a prototype 3D printer extruder to support continuous fiber 3D printing

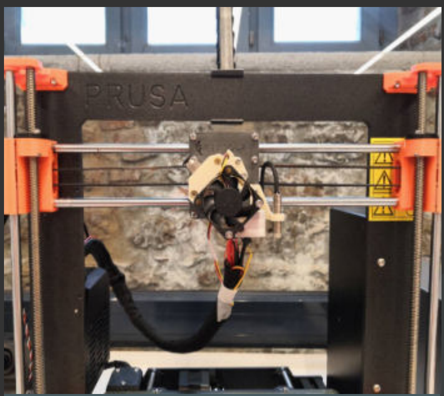
Towards the development and validation of new sets of performant thermoplastic composites, BioG3D is developing an open-materials prototype 3D printer extruder for composite production with tailored fiber placement, enabled by Coaxial Continuous Fiber 3D Printing.

The redesign and modification of an FFF printhead was conducted. Alterations and prototyping of the modified print-head integration bracket, X-axis carriage grip, fan holder and heat block were conducted in order to support in-nozzle impregnation of twisted Carbon Fiber (CF) multi filaments with thermoplastic materials in filament form.

Prototype 3D printer extruder model for Coaxial Continuous Fiber 3D Printing

The testing of the prototype 3D printing feeding system is in progress, by employing custom G-code scripts in order to fine-tune material feedrate, printing temperature and printing speed.

Advanced toolpath generation algorithms are also in development to demonstrate a digitalized manufacturing workflow of 3D printed composites with complex bioinspired structures and advanced materials.



Modified print-head assembly, mounting and testing in Prusai3 MK3S

During the next phase, the printability assessment of thermoplastic matrix and interaction with continuous fiber reinforcement will be conducted to assess properties and performance of the output 3D printed composite material/structures and provide feedback for process optimization and fabrication strategies to be pursued.

This approach allows to produce free-form, CF composites, with continuous fiber reinforcement, without the need for expensive facilities and equipment, such as autoclaves and complex rigid molds, while combining low-cost equipment and advanced feedstock materials for an application-driven production of high-performance components.

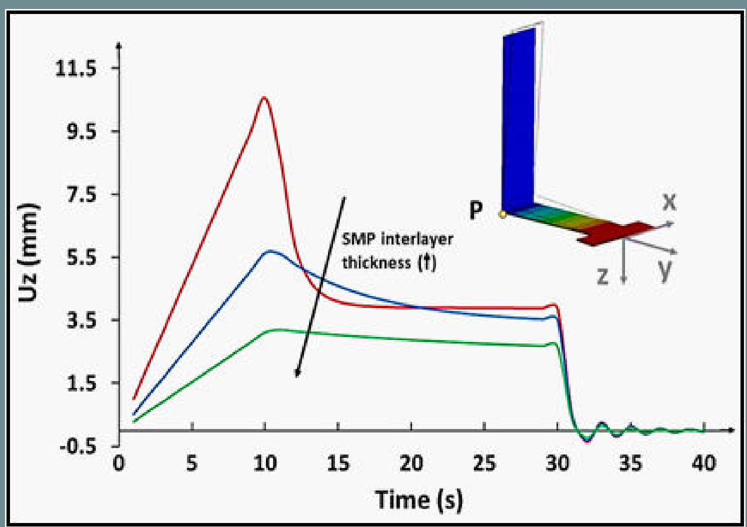
UNIROMA

Numerical modelling of shape memory polymer composite structures

The Department of Industrial Engineering of the University of Rome Tor Vergata has started its numerical modelling activity to simulate the shape memory behavior of smart composites. The case study is the prototyped smart finger prototype which has been investigated to validate numerically experimental findings.

In the developed FEM model a shape memory polymer (SMP) interlayer was placed between carbon fiber reinforced (CFR) skins.

- The first part of the simulation aimed at evaluating the stiffness of the shape memory polymer composite (SMPC) finger by varying the number of the CFR skins.
- The second part aimed at evaluating if the triggering effect of the polymer transition for shape memory behavior could be modelled by means of changes in the material damping coefficient.



Positive results will allow implementing a full thermomechanical analysis to replicate the experimental shape memory curves, and having a powerful instrument to predict the behavior of large grabbing devices during operation.

The next steps will be the simulation of large grabbing devices to find the best strategy for the memory and recovery phases. Numerical analysis and manufacturing technology are a winning combination for the development of efficient and reliable SMPC devices for “in Space” and “on Earth” applications.

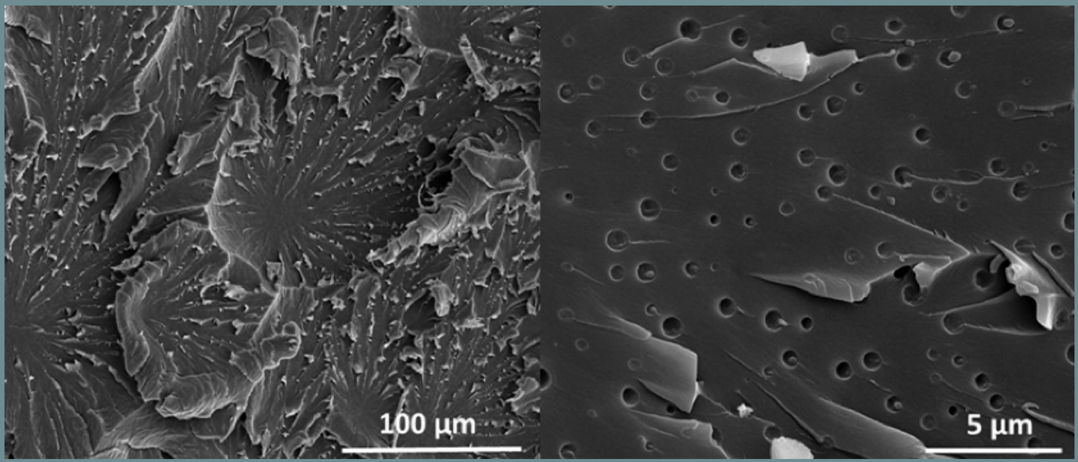
INEGI

Multifunctional nanocomposites and carbon fiber reinforced polymers (CFRPs) with enhanced performance

INEGI developed multifunctional and multiscale CFRPs with improved mechanical performance aiming to be used on the demonstrator production.

According to the mechanical characterization performed, the introduction of different loadings of block copolymers (BCPs) in the epoxy matrix, resulted in nanocomposites having enhanced tensile and impact strength, up to 64 and 25 %, respectively.

Based on the scanning electron microscopy (SEM) images bellow, itis possible to observe the formation of nanostructured BCP spheres that are homogeneously dispersed in the matrix and the roughness of the fractured surface of the tensile specimens, evidencing the presence of toughening paths.



Multiscale pre-impregnated materials and CFRPs were also prepared using modified matrices with BCPs for double cantilever beam (DCB) tests. IThe modified CFRP composites with 2.5 and 5.0 wt. % BCP exhibited impressive improvements on the interlaminar fractured toughness between 55 and 83 %, respectively.

NTUA

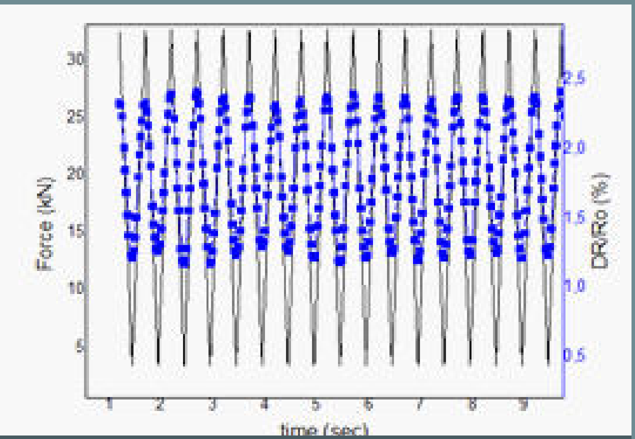
Electromechanical measurements on carbon fibre reinforced epoxy composites

NTUA performed electromechanical measurements on carbon fibre reinforced epoxy composites. The specimens were subjected to fatigue testing. The carbon fibre fabrics were prior treated with CVD, in order to graft carbon nanotubes on their surface. During fatigue testing, the electrical resistance of the CFRPs specimens was recorded.

At upper image the electrical contacts configuration during electromechanical measurement is shown.

These specific electrical contact configurations could record electrical signal proportional of the loading and unloading of specimen. Throughout testing, damages that occurred in the specimen were recorded as changes in the electrical resistance signal, until the failure of the composite. In the graph, with black is the applied force and with blue the recorded resistance change. These preliminary tests indicate good damage sensitivity.

Electrical contacts configuration during electromechanical measurement.



Electromechanical results:applied force (black) and electrical resistance change (blue) versus time.

STRATOSPHERE

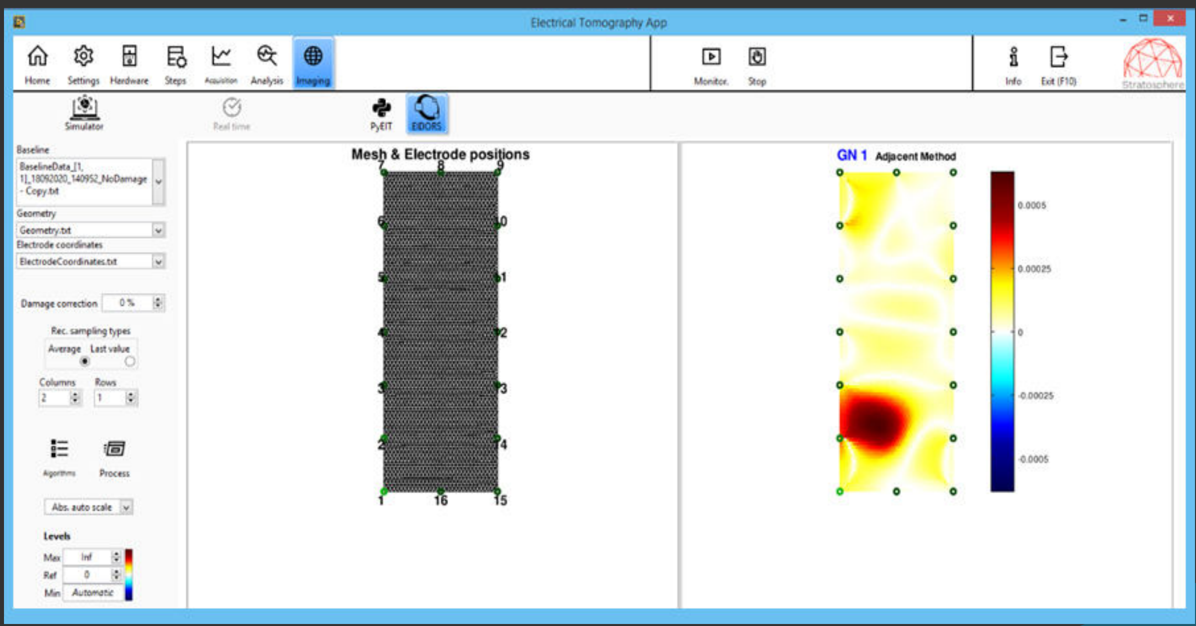
Electric Impedance Tomography (EIT)

Stratosphere SA, is in the final phase to test and validate its 16 electrodes Electric Impedance Tomography (EIT) equipment. Some tests are being carry out with carbon fiber reinforced polymers (CFRP) with graphene oxide mixed on the matrix developed in the project, and commercial available CFRP’s.

The objective is to have an integrated platform with hardware to acquire and generate the electric signals, software to control all the steps, simulation and optimization in the same packet.

It is possible to read a 2D geometry from a CAD file and make all the analysis with simulation and compare the results with a real structure with electrodes bonded on it and the signal’s generated and read by the hardware developed to validate all the concept. Some useful tools are incorporated, like a virtual electrode position software to select the best points to put the electrodes using a simulated environment. A signal integrity tool was developed to verify the quality of the measurements took during the readings with the hardware.

The software tool gives an image with the absolute or relative conductivity of the measured sample, with different algorithms to detect damage on its interior.



This development was start at the beginning of the Smartfan project, with several improvements during the duration of the task, starting with 8 electrodes version to have 16 electrodes actually with several solvers to predict the electric conductivity.

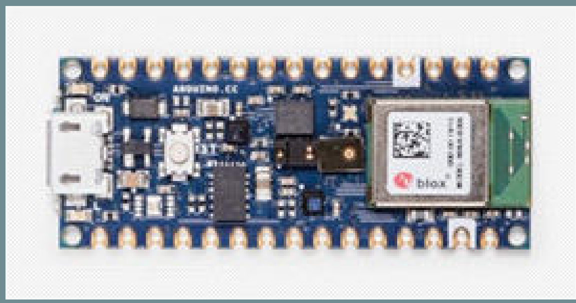
Actually the EIT equipment is in a final phase with some cases to validate the algorithms and the electronic hardware to achieve TRL6.

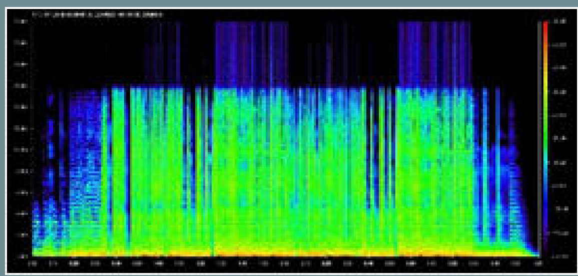
TECHEDGE

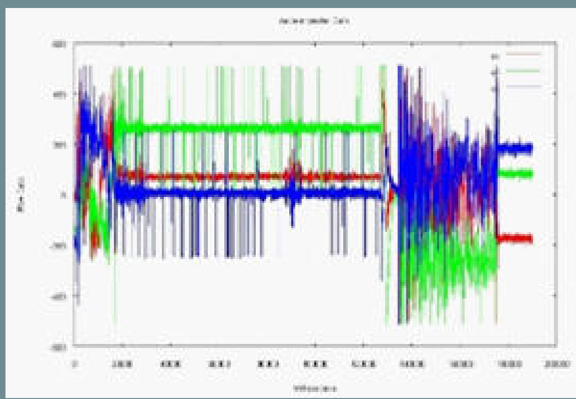
Development of AI models

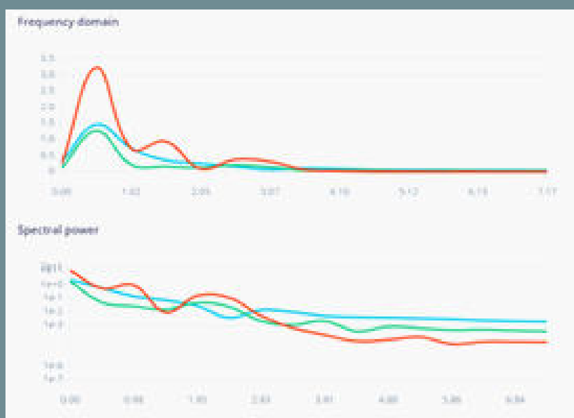
Last month's Techedge efforts were focused on developing AI models ready to be deployed on ultra-low power IoT devices (as the Arduino BLE 33 Sense), working on real-time data acquired using several types of sensors (audio, roto-vibrational, video). A key aspect here is the fine tuning of the features extracted from data, since a proper features engineering allows to:

- Decrease the amount of dirty data to be ingested by the AI, thus decreasing the computational cost of the AI itself
- Increase the AI accuracy
- Gives news insights on the problem which is under investigations.









Our principal feature engineering approach is based on spectral analysis techniques.
We tested ultra-low power AI application for anomaly detection of tests components using vibrational a sound data. This testing step was necessary in order to optimize neural network models in the perspective to be used with the data coming from SmartFan partners. Following this step, we plan to perform several tests on different architectural solutions, using different neural network configurations as:

- RBM
- Autoencoders
- Convolutional 1D NN

IRES

CNT/CNF High energy aerosol generation nanomaterial Dispersion/Suspension processes SMARTFAN Decision tree Safety recommendation report

Release of droplets and primary nanoparticles or agglomerates in the work environment is expected from unenclosed, high energy nanomaterial suspension/dispersion operations.	
Exposure risks present **High Exposure Probability**	• Release of primary nanoparticles and nanoparticle agglomerates, Inhalation & dermal exposure • Release of droplets containing nanoparticles, Inhalation & dermal exposure • Inhalation & dermal Exposure during vessel cleaning/maintenance • Contamination of work surfaces & secondary resuspension/exposure • High exposure risk upon accidental spillage
RECOMMENDED CONTROLS	
Workplace Concentration levels for airborne CNTs/CNFs should be kept below 0.01 fiber/cm^3 or 1μg/m^3 as 8h TWA	
Safer nanomaterial design/purchase	If applicable, prefer: • Shorter nanotubes (<5 μm) • Tangled nanotube formations • Thicker structures • Weak surface charge tubes • Highly purified nanotubes • Biocompatible-material functionalized nanotubes *Safer...*   *The main goal of safer-by-design strategies for Carbon based high aspect ratio nanomaterials is to diminish their biopersistence, determined to a great extent by their fibrous nature.* *...Hazardous* 
Engineering controls	• Perform process within an enclosed cabin, glove box or custom enclosure for large size vessels • Perform process within a fume hood/custom partially enclosed ventilated setup • Exhaust air should be filtered using a HEPA filter class H14 • Use local exhaust ventilation adapted to the vessel to remove emitted particles • Ensure area meets General Dilution ventilation requirements of >10 Air Changes/h 
Administrative controls	• Isolate area of high-energy mixing processes from other non-nanomaterial work activities. Access to area to authorized & nanosafety-trained persons only. Restrict access to area to individuals without PPE. • Ensure proper labeling of workroom for presence & potential exposure to nanomaterials • If possible, monitor the process progression remotely • Clean work surfaces & enclosure interior walls after finishing each process/batch, using wet-wiping methods. Do not dry sweep, or use water jets or compressed air. • Install a sticky mat in the workroom entrance. Disposable overshoes are also recommended. • Perform regular maintenance and performance testing of extraction ventilation equipment   
Personal Protective Equipment	• Use an FFP3 respirator for the whole duration of the process, as well as for vessel maintenance and cleaning activities. If no engineering controls are active, use full/half face respirator with class P2 or P3 particulate filters. • Be equipped with nitrile, latex or neoprene gloves of >100μm thickness and <1.5 AQL index. Wear two layers of gloves if no engineering controls are active • Wear laboratory-appropriate clothing (long pants, long-sleeved shirt, no jewelry), and non-woven material coveralls (e.g. Tyvek). • Use safety goggles to protect eyes from all sides   
Spillage containment Protocol	*1. Use chemical sorbent pillows to place a barrier and surround the area of the spillage, so that no further contamination is possible.*  *2. Deposit absorbent pads to soak up the liquid, using as many as needed to cover the whole spillage surface. Wait several minutes for the pads to absorb the liquid (time required typically listed in the product description). Once the liquid has been absorbed, remove the pads and if needed, carefully wipe up any residual material using minimal force.* *3. A final wipe should be performed with a paper towel and water. Dispose of all materials, as well as the clothing that has come in direct contact with the nanomaterial suspension as nanomaterial waste.*

Increasing effectiveness & priority

SmartFAN

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