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# Estimation of human body attenuation as a propagation channel for standardized HBC communications

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Human Body Communications (HBC), which has been standardized around 21 MHz (IEEE 802.15.6 standard), potentially offers more favorable propagation conditions than usual wireless technologies such as ZigBee, or Bluetooth. However, due to their sensitivity to the close environment, the signal attenuation cannot be accurately determined using lab equipment. Therefore, to perform attenuation estimation under realistic conditions, a HBC transceiver operating at 21MHz, built around a microcontroller and a simple analog front-end was designed. The proposed transceiver is energy self-sufficient (via a coin cell battery), wearable on the human body and allows the measurement of the path loss (without the use of external devices) from the estimation of the voltage emitted and received via implantation of Goertzel's algorithm. Finally, the prototype designed allowed to measure a signal voltage attenuation between 40 and 50 dB for communications ranging from 20 cm to 1.5 m.

**Keywords:** Transceiver, Goertzel Algorithm, voltage estimation

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# CICCs tomographic analyses for coupling losses prediction with COLISEUM model and experimental measurement

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Tokamaks coils are wound with long lengths of cables including hundreds of superconducting and copper strands twisted together into multiple stages to form Cable in Conduit Conductors (CICCs). Magnetic field variation induce AC losses, which correspond to coupling and hysteretic losses addition. They dissipate power in the coils during machine operation and can be critical for being source of resistive transitions and possible damages. Thus, they should be accurately predicted.
CEA developed since several years the analytical model COLISEUM (**CO**upling **L**osses analyt**I**cal **S**tages cabl**E**s **U**nified **M**odel) to predict coupling losses at various conductor scales. Geometrical (cabling radii, twist pitches) and electrical (inter-strand and inter-bundle conductances) parameters of each stage are the model inputs. The most recent model version addresses the coupling losses for a full CICC, accounting contributions from the strand to the nth-stage of the cable.

This work is about the use of CICCs tomographic examinations to determine realistic input parameters for the COLISEUM model. These tomographic analyses allow determining the different stages of a CICC and their associated effective geometrical parameters. In the following, those parameters will be used to determine the electrical parameters. The latter are especially targeted as driving currents and therefore coupling power.
We measured by magnetization method in JOSEFA facility, at CEA Cadarache, the AC losses of all samples that underwent tomography. We conducted measurement on various CICCs of different aspect ratio and void fraction to explore a broad range of configurations. We used effective parameters from tomographic analyses as COLISEUM input to compare the model with experimental results.

**Keywords:** Fusion magnets, Cable in Conduit Conductors, AC loss, Tomography

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# Fluid mechanics and soft matter serving forensic sciences

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After a bloody event, Crime Scene Investigators (CSI) can find different pieces of evidence. Among them bloodstains (pools and drops) are one of the most encountered. According to their interpretations, CSI can reconstruct temporally and spatially, the crime scene. They analyze the size, shape, and location of pools and drops to offer different assumptions and conclusions. Nowadays, courtrooms require reliable and scientifically validated methods and techniques of interpreting bloodstains to avoid wrongful condemnation. In our research project, an effort has been undertaken to improve and develop new methods for CSI, by incorporating fluid mechanics, heat and mass transfer into forensic sciences situations.

Spreading, wetting, and drying of human whole blood pools is studied experimentally. Blood is considered as colloidal suspension with complex rheological behavior. We evidenced that the equilibrium area of a pool depends on the surrounding conditions. Phase separation, during spreading, is driven by relative humidity and is explained by the competition between coagulation and evaporation. In addition, the drying kinetics of blood pools is modeled, and a theoretical diffusion coefficient of blood pool into the air is determined. These findings prompted the development of a smartphone application to estimate the time of the crime, which is based on the drying morphology of blood pools and image processing.

The impact of blood drops on different substrates is also studied and, more precisely, our interest is focused on passive stains. We investigate the impact of drops on the wooden floor (non-porous) and jeans fabrics (porous). We report that blood drops spreading and receding dynamics depend on temperature and wettability of the substrate. Surprisingly, the relative humidity also seems to be very important since it has an influence on evaporation. The maximum spreading factor and the receding one were found to be a function of the relative humidity.

**Keywords:** Wetting, Drying, Blood, Drops and Pools, Forensic science

*Speaker

# Metasurface absorbante dans les bandes visible et infrarouge : conception de nanostructures aux propriétés optiques et électriques contrôlées

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Plasmonic nanoparticles are key to the realization of selective light absorbers, and especially metallic nanoparticles that exhibit tunable optical properties with implications in multiple fields such as photovoltaic, photodetectors and optical filters. Among those nanoparticles, metallic split-ring resonators are metamaterials with optically induced magnetic responses allowing unique possibilities for controlling light and enhance absorption in the visible and near IR domains depending on their geometric parameters.
The objective of this research is to show the enhancement of absorption at optical frequencies by not only designing a metasurface made of silver split-rings with realistic geometric parameters but also providing a first proof of concept of those tunable circular nanorings entirely made by scalable bottom-up approaches.

First, Finite Difference Time Domain (FDTD) simulations were performed to optimize the silver nanoring geometric properties thanks to a parametric study (inner, outer diameters, thickness, split-ring gap, array periodicity). This showed full control on resonance peaks and absorbance enhancement in the visible and near IR.
Next, we showed the realization of circular silver split-ring arrays on a large area via bottom-up techniques. Silver single nanocubes (synthesized in solution via the polyol process) were self-assembled in Polydimethylsiloxane (PDMS) templates previously nanostructured with a pre-defined split-ring motif. Epitaxial nanowelding techniques at low temperature were then employed to connect the individual nanocubes together to obtain a continuous material.

**Keywords:** Metasurface, silver nanorings, absorption, nanostructure

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# The role of geometrically necessary dislocations flow in viscoplastic behavior of polycrystalline uranium dioxide

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Polycrystalline uranium dioxide (UO2) is commonly used as nuclear fuel, in Pressurized Water Reactors (PWRs), in the form of cylindrical pellets. At high temperatures, the viscoplastic behavior of the fuel is controlled by the dislocation motion. Microscopic investigations on deformed pellets (1) have highlighted the development of dislocation substructures: the dislocations were mostly organized in sub-boundaries, subdividing the grains into sub-grains.
The formed sub-boundaries are associated to the presence of Geometrically Necessary Dislocations (GNDs) (2). Such dislocations induce a lattice curvature in order to accommodate local deformation produced among grains and rearrange in dislocation walls. At the polycrystal scale, one should consider the coupling of GNDs with Statistically Stored Dislocations (SSDs). SSDs are the dislocations of opposite orientation that mutually cancel when brought together, have no effect on lattice curvature, and only contribute to the plastic flow. Classical crystal plasticity models evaluate the deformation by the single contribution of the SSDs. To include the crystal plasticity of GNDs, an approach based on Field Dislocation Mechanics (FDM) theory (3), which models the deformation due to GNDs glide on slip systems, is developed. GNDs densities are obtained through incompatible plastic deformations between adjacent grains with different orientations, following Kröner's equation (2).

First, the glide velocity of GNDs and SSDs densities is identified on UO2 single-crystal tests. Then, the proposed model is used to simulate an imposed speed compression test of a polycrystal of UO2. Mechanical equilibrium and Kröner's equation are solved using Fast Fourier Transform (FFT). The test shows: accumulation of GNDs at the grain boundaries, glide within the grains, and the formation of sub-grains. Results predicted by the model demonstrate, qualitatively, a good agreement with the experimentally observed dislocations substructure in deformed UO2.
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**Keywords:** Geometrically Necessary Dislocations (GNDs), Field Dislocation Mechanics (FDM), Viscoplasticity, Dislocation substructures, Fast Fourier Transform (FFT).

# Experimental study of the Richtmyer-Meshkov instability in spherical geometry

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Richtmyer-Meshkov instability occurs when a corrugated interface between two fluids is accelerated by a shock wave. It is of primary importance, particularly in inertial confinement fusion, where it triggers a mixing between fuel and shell, preventing the ignition of the reaction. This instability has been widely investigated in planar geometry, and, more recently, in cylindrical geometry, to consider convergence effects. In this study, we experimentally investigate the Richtmyer-Meshkov instability in spherical geometry, where convergence effects are more pronounced. First, we demonstrate the possibility of generating a spherical converging shock wave in a conical chamber using the impedance mismatch between different gases. The shock wave propagation is tracked using a high-speed camera, a laser sheet setup, and micron-sized particles (oil droplets or smoke) seeding for planar Mie scattering. Due to the conical geometry of the chamber, optical distortion correction becomes challenging. A machine learning algorithm is used to reconstruct the undistorted image of the flow. This enables the study of the shock wave sphericity and its trajectory. The next step is to apply this experimental technique to study the Richtmyer-Meshkov instability in such a geometry, where the spherical shock wave interacts with a corrugated interface between different gases. The development of the instability is again monitored thanks to the high-speed camera and planar Mie scattering. We study both the displacement and the growth of the perturbations at the interface and compare it to numerical simulations and new theoretical predictions.

**Keywords:** shock waves, hydrodynamic instability, experimental

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# Synthesis of monodisperse polyurea microcapsules with controlled size and thickness to encapsulate sun filters

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Encapsulation is a technique that allows the isolation of one or more compounds in a capsule to preserve them from interactions with their external environment. **It is fundamental to control the size and thickness of the capsules** because they have a direct impact on their life span, permeability, mechanical resistance and release properties.
**The objective here is to encapsulate a sun filter to prevent it from penetrating the skin**. It is therefore necessary to have capsules that are larger than the micropores of the skin, sufficiently resistant and therefore thick.

We choose to synthesize polyurea shells with the reaction (Isocyanate + Amine → Urea) by **interfacial polymerization.** In a first step, droplets of organic phase containing the isocyanate and the species to be encapsulated are formed in water. Once stabilized, these droplets are poured in a water phase rich in amine. When in contact with the isocyanate, this amine polymerizes at the surface of the droplets to form a polyurea shell.
The size of the droplets is controlled by microfluidic flow-focusing, and the final thickness of the capsules is directly proportional to the concentration of isocyanate in the organic phase. **With this method, it is possible to encapsulate sun filters in monodisperse capsules of controlled size** (20 to 100 micrometers), **and adjustable thickness** between 500 nanometers and 2 micrometers **as targeted.**

**Keywords:** Encapsulation Microfluidics Polyurea Interfacial polymerization

*Speaker

# Modeling and simulation of the cavitation phenomenon in a turbopump: a two-phase flow approach

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Liquid propellant rocket engines provide propulsive effect by ensuring the ejection of gases at high temperature and pressure into a nozzle. These gases are obtained from the combustion of the propellant located in the tanks. The routing of these cryogenic fluids to the combustion chamber requires the use of turbopumps able to provide the conditions required for the combustion. As the fluid travels, its local pressure may drop abruptly as a result of the pump suction. When the saturation pressure is reached, vapor bubbles and cavitation pockets may appear: this is the cavitation phenomenon. These structures, when passing through the blades, can cause a temporary overspeed of the pump, a blocking of the flow as well as various mechanical instabilities. In order to better understand this phenomenon and to limit its impact, my thesis work aims to propose a numerical modeling of this type of flow. The formation of steam when cavitation is encountered requires, at the same time, to take into account the two-phase aspect of the flow and the compressibility of the phases. The family of two-phase flow models with diffuse interfaces is an ideal candidate for these needs and has been successfully used in the past to model cavitating flows. The rotation of the blades must also be considered, for this purpose, the pressure-velocity equilibrium diffuse interface model has been written in a rotating reference frame using the Moving Reference Frame method. In this approach the mesh is fixed and the rotational motion is translated by adding additional terms in the system of equations such as the Coriolis and centrifugal forces. The study of the performance of a turbopump inducer is carried out in a cavitating regime and compared with experimental data showing the ability of the present work to predict cavitating flows in such conditions.

**Keywords:** cavitation, compressible, two, phase flows, diffuse interface models

*Speaker

# Model and simulation of the surface chemical reactions interaction between a hypersonic flow and an ablatable Thermal Protection System (TPS): Application to atmospheric reentry

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The atmospheric reentry of space objects is the place of many physical phenomena which immerse them to extreme conditions. The strong detached shock created ahead space objects transmits very large heat fluxes to the TPS. The huge energy to be dissipated requires the use of TPS made of ablative materials to ensure the survival of the objects' structure. The multi-physical character and the extreme conditions intrinsic to ablation make it difficult to experiment those phenomena in laboratory. Even today, TPS design is based on important safety factors. Numerical simulation appears to be an essential tool for reducing these safety margins, and among others, the weight of the TPS. This thesis is part of this process of improving computational tools related to ablative degradation. The work in progress focuses on the degradation due to pyrolysis and surface chemical reactions of ablative carbon composite materials used as TPS for hypersonic reentry vehicles. The strategy is based onto a coupling between the finite volume material response solver MoDeTheC and the multi-physics platform CEDRE using the Computational Fluid Dynamic (CFD) solver CHARME, both developed at ONERA. Detailed (12 reactions included reactive free carbon bond) models of oxidation, nitridation and sublimation of Duffa and Zhluktov et al. have been implemented in MoDeTheC. Simulation of the trajectory point of the experimental flight RAM-C I at an altitude of 40 km and Mach 23.474 using the Park's Earth's atmosphere model has been performed. The coupling strategy consists in the exchange at the object surface of pressure, composition, heat fluxes from CEDRE, pyrolysis gases mass fluxes, ablation mass and energy fluxes and temperature of the wall and of the gases from MoDeTheC. The results of the simulation allow to obtain the regression rate of the wall and to analyze the interaction between the flow and the TPS.

**Keywords:** Hypersonic, ablation, atmospheric reentry

*Speaker

# A van der Waals Heterojunction Based on Monolayers of MoS2 and WSe2 for Solar Water Splitting

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The production of clean, sustainable and economical hydrogen is one of the major challenges to face the depletion of fossil fuels and their detrimental environmental impacts. Among others, solar water splitting (SWS) has been widely studied as a promising technology for generating carbon-free hydrogen. Here, we propose a monolithic SWS system based on a *Z-Scheme* van der Waals heterojunction (vdWH) using monolayers of transition metal dichalcogenides (TMD) as active core materials. This architecture provides the bias required for electrolysis (Voc $>$ 2 V) while maximising the absorption of solar energy with small bandgaps. MoS2 and WSe2 are *a priori* chosen for the anode and cathode respectively because of their electrochemical and optical properties. Two distinct regions make up the active core. The first is a MoS2/hBN/WSe2 heterojunction where hexagonal boron nitride (hBN) is used to isolate the two TMDs. The electrons (holes) photogenerated in WSe2 (MoS2) are consumed by the hydrogen (oxygen) evolution reaction. In the second region, hBN is removed to ensure the recombination of the extra carriers (i.e. holes in WSe2 and electrons in MoS2). Membranes of mesoporous transparent metal oxides support the heterojunction and enable water to reach the active part. To understand the behaviour of our system, we developed a multiphysics model that computes the solar-to-hydrogen (STH) efficiency of the system. In this model, we use *ab initio* calculation to determine the optical properties of the active materials and we implement the detailed balance method and the Butler-Volmer kinetics to simulate the photoelectrochemical response. Under realistic operating conditions, the system achieves an STH efficiency greater than 15%. Since our system is wireless and requires simple manufacturing processes (exfoliation), this result is remarkable.

**Keywords:** Solar Water Splitting, van der Waals Heterojunction, Photoelectrochemistry, Solar To Hydrogen, Transition Metal Dichalcogenides

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# PS-TDLS: temperature-dependent lifetime spectroscopy for defect characterization in silicon

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In Silicon-Device fabrication, the various processing steps can be sources of impurity contamination. Metal impurities are detrimental to silicon integrated circuits and solar cells as they degrade their electrical properties and performances. Electrically active metal impurities introduce charge carrier recombination centers and degrade the minority carrier lifetime. It is therefore important to identify the nature of these impurities through their characteristics: the capture cross section

**Keywords:** impurities, lifetime, characterization

*Speaker

# Axisymmetric particle rotations in shear flow

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We experimentally investigate the rotational dynamics of a neutrally-buoyant axisymmetric particle in a viscous shearing flow.
A custom-built shearing cell and a multi-view shape reconstruction method are used to obtain direct measurement of the period and the angular phase of the Jeffery orbits (Jeffery, 1922). We report good agreement with the data available in the literature for the viscous regime (Trevelyan and Mason, 1951; Goldsmith and Mason, 1962) and present novel results on the influence of small fluid inertia over the dynamical behaviour of the rotating particles in order to compare them with the most recent theories (Einarsson et. al., 2015; Dabade et al., 2016).

**Keywords:** rotation fibre inertia

*Speaker

# Acoustic lens design for in-vitro cell stimulation: A numerical study

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In the early 1950s, the first clinical observations on the effect of *Ultrasound Stimulation on Bone Regeneration* (*USBR*), were reported. Then, in 1994, the *FDA* (*Food and Drug Administration*, USA) authorized the use of *USBR* for clinical application. However, the effects of the mechanotransduction (the ability to trigger a biological response by using a mechanical stimulation) are still unclear and *USBR* remains controversial. To better understand the interaction between ultrasound and bone cells, the development of *in-vitro* experiments is a key step.
One of the first challenges was to characterize and monitor the ultrasound dose delivered to the cells inside a Petri dish. In order to avoid perturbating phenomena such as multiple reflections and standing waves, an innovative experimental set-up including an anti-reflection cover, has been proposed. In this set-up, bone cells are seeded in a Petri dish (the surface covered by the cells measures 35 mm in diameter) and they are stimulated by using a 1 MHz transducer of 13 mm diameter. However, experimental results showed that the intensty distribution is heterogeneous and concentrated in the middle of the Petri dish, so the cells will not receive the same acoustic intensity, when they will be seeded in the dish.
In order to enlarge and homogenize the acoustic intensity distribution inside the Petri dish, an acoustic lens is designed. In this study, a numerical model using *Finite Element* (*FE*) method is developed under *COMSOL Multiphysics* to reproduce the experimental set-up, and guide the design of this lens. Different configurations are thus tested in order to optimize the geometrical and material composition of the lens.

**Keywords:** Bone regeneration, ultrasound cell stimulation, acoustic intensity, experimental and numerical modeling

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# Virtual Sound source Integration in Electric Vehicle Interior

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With the development of electric motor vehicles, the domain of automotive sound design addresses new issues, and is now concerned by creating suitable and pleasant soundscapes inside the vehicle. For instance, the absence of predominant engine sound changes the driver perception of the dynamic of his car. Previous studies proposed relevant sonification strategies to augment the interior sound environment by bringing back vehicle dynamics with synthetic auditory cues. Yet, users report a lack of blending with the existing soundscape. In this study, we analyze acoustical and perceptual spatial characteristics of the car soundscape and show that if the sonification sound matches spatial characteristics of traditional engine sound, the global environment is perceived as more coherent.

**Keywords:** Spatial Audio, Sound Design, Automotive Audio, Augmented Reality

*Speaker

# Multi-scale granular mechanics using MPM x DEM

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The prediction of granular materials' behaviour is challenging because of their complex microscopic structure. The Discrete Element Method (DEM) is a numerical model very suitable to granular materials since it models all grains and their contacts, providing an accurate description of the material's response to any loading condition. However, at large scales, the enormous number of grains to be modelled makes its computational cost too expensive. Constitutive law based methods such as the Finite Element Method (FEM) reach easily larger scales due to their assumption of the material's continuity, but most constitutive laws fail to describe accurately granular materials' behaviour for many loading conditions. Indeed, such models require many parameters often determined empirically for only a few loading paths. Describing the behaviour using DEM instead of a constitutive law makes FEM-like methods more suitable to granular materials and grants access to larger scales. Such a coupling can be made by performing a DEM simulation at each Gauss point considering a periodic Representative Volume Element (RVE) of material. The history of the material is thus naturally accounted for in all RVEs, thanks to the thorough material's description provided by the DEM. Among the FEM-like methods, the Material Point Method (MPM) was formulated as an hybrid Eulerian-Lagrangian method to handle accurately large deformations.
A MPMxDEM coupling is proposed to study the behaviour of a numerical sample of Camargue's sand, insights on its microscopic structure is then given.

**Keywords:** Multi, scale, DEM, MPM, granular materials, large deformations

*Speaker

# Fluid-structure interactions of flexible rotors

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Flexible rotors can be favourable in certain applications: convertible aircraft, drones with stowable rotors, or small unmanned aerial vehicles (UAVs) requiring damage-tolerant blades. In addition, an interest has grown recently in the development of hybrid UAVs capable of operating in both air and water.
This study is a combination of experimental and numerical study of flexible rotors. The first part of this study is concerned with the experimental investigation of a simplified small-scale rotor operating in water. The tested rotor of radius 88 mm and chord 20mm consists of a single rectangular blade, made of low-density polyethylene. In these experiments, the blade deformation and flow field are extracted at variable tip speed ratios, tip Reynolds numbers (up to $Re$ = 2e5), and blade pitch angles (between -10○ and 10○).

In the second part, a fluid-structure interaction model is developed to evaluate the static and dynamic deformations of a flexible rotor blade. The blade is modelled as a 1D structure, based on the solution of 3D nonlinear elasticity equations. The rotor wake is obtained using a helical vortex model without wake expansion.
Comparisons are made between the theoretical model and the results of the experimental survey. The main parameters in this comparison are the flapwise bending magnitude, the induced twist angle and the induced axial velocities in the rotor plane. A good agreement between the numerical model and the experiments is demonstrated for a certain range of flow parameters.

**Keywords:** Flexible rotor, Fluid, Structure Interaction, Particle Image Velocimetry, Digital Image Correlation, Vortex Ring State, Vortex Modelling, Kirchhoff Equations

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# Circuit design of an innovative logic/memory CUBE for In-Memory-Computing

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With the massive deployment of edge near-sensor processing and artificial intelligence, the historical Von Neumann architecture used in most of our electronic devices suffers from a serious bottleneck due its use of energy-hungry and slow data transfers between memory and processing units. To overcome this challenge, a new computing paradigm, called "In-Memory Computing", rises to be a solution. The idea is to perform the logic operations directly inside the memory instead of using external processing units, thus drastically reducing data movements and their associated cost. One of the most appealing implementations of such approaches rely on emerging nonvolatile memories such as Resistive RAMs (RRAM).
Based on a new transistor technology called "nanosheet transistors", the CEA LETI is developing an innovative 3D RRAM memory cube to perform In-Memory Computing. During my phD, we worked on defining this 3D cube architecture in order to construct the first non-volatile 3D NOR memory, providing a random access to all the memory elements with a high parallelism. We explored, evaluated and improved a RRAM-based computing logic family called "Scouting Logic" on the cube, and based on transistor characterizations and electrical simulations, we demonstrated the cube capability to perform logical operation with up to four operand in parallel per pillar. To overcome the well-known high RRAM bitcell variability for neural network applications, where the number of operands can be in the order of thousands, we proposed an ultra-robust and energy-efficient capacitive RRAM-based neuron that can be plugged on top of our 3D cube. To fully demonstrate its capabilities, we fabricated and characterized a testchip, which proved the ultra-high robustness of our approach even with degraded memory performances. Upcoming work may consider evaluation of our approach at the system level.

**Keywords:** RRAM memory, stacked nanowires, junctionless transistors, OxRAM, In, memory computing (IMC), Scouting Logic, Binary Neural Network (BNN), XNOR, POPCOUNT.

*Speaker

# Multi-scale cohesion force measurements for cemented granular materials

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Cemented granular materials are abundant in nature. They constitute a broad class of geomaterials including any material where packed particles are bridged by cement. This definition incorporates several natural materials such as sandstones and breccias as well as many engineered materials such as asphalts, mortars etc ... A particular situation deals with cemented granular soils, when brittle solid bridges connect the particles two by two. Characterizing this type of soil, somewhere between a tough granular soil and a soft sandy rock, is crucial for the understanding of geomechanical phenomena such as erosion, excavation, or fracturation.
Here, we use home-made artificial cemented granular materials prepared from a mixture of paraffin and spherical glass beads. The cementation strength of our material is quantified using laboratory tests designed and carried out for investigation at different scales. Indeed, we measured the tensile yield strength both at the macro-scale of a cemented sample and at the inter-particle micro-scale of a solid bond between two bonded particles extracted from the previous macro-scale sample. Note that a statistical approach is necessary because of the very high dispersion observed for these microscopic measurements. A parametric study has been performed by varying the granular material properties (bead diameter, paraffin content), and the dimension of the macro-scale tensile test.
The hydro-mechanical behavior is next investigated by applying a localized underflow on a layer of artificial cemented soil for different heights and particles diameters. Under critical conditions in terms of flow-rate and overall pressure drop, the cemented layer is hydraulically fractured and three different types of rupture were observed: global uplift, median crack, and fluidized path. All are strongly controlled by the boundary conditions of the system.

**Keywords:** Cemented granular material, fluidization, erosion, mechanical characterization and uplift

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# Thermal hydraulic properties characterization in porous media of cable-in-conduit conductor with nitrogen gas flow

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Cable-in-conduit conductor composing superconducting magnets of tokamak devices are cooled with helium forced flow at cryogenic temperature, in order to provide efficient heat removal and thermal stability of the superconducting state. The bundle region of such conductor is a twisted multistage arrangement of strands inserted in a jacket. Flow parameters and heat transfer mechanisms in this complicated geometry are studied in order to evaluate effective thermohydraulic properties at macro scale ("porous media approach"/upscaling). Therefore, steady state and transient experiments were performed to measure friction factor and convective heat transfer coefficient (HTC) respectively. The experimental loop uses nitrogen gas as working fluid at equivalent conditions to supercritical helium forced flow regarding Reynolds and Prandtl numbers, ranged from nearly 100 to 10000 and 0.6 to 0.7 respectively. The hydraulic diameter used as characteristic length is deduced from X-ray tomography. The Darcy-Forchheimer flow model is applied on a large set of JT-60SA toroidal field coil cable-in-conduit steady state measurements for permeability and inertia coefficient assessments. Preliminary studies of optimal conditions required to determine the HTC between fluid and strands of tested samples were performed and followed by a first campaign of transient heat pulse experiments. A simplified three temperatures (fluid, strands, jacket) model solved with Fourier transform and a more detailed numeric one were developed and used to analyze the fluid outlet system answer to a fluid temperature step at the inlet. An inverse procedure based on along the least squares method allow us to assess the HTC. The 1-D transient model is an equivalent and fictive continuous media composed of two phases (strands/nitrogen) with effective properties related to porosity, thermally coupled by convection with the jacket. This model also allows analyzing effects of the fluid compressibility due to pressure losses and of the longitudinal thermal conduction in solids on the parameter characterization.

*Speaker

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**Keywords:** Fusion magnet, Cable in conduit, Fluid flow, Friction factor, Heat transfer coefficient, Steady state and transient regimes

# Towards restaurants powered by Scheffler reflectors - Standard performance test of a basic solution

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Scheffler-type cookers seem to be promising among solar cookers because they can provide sufficiently high power and temperature for various cooking processes and, they allow to keep the parabola and the focus point at stationary positions throughout the year. The purpose of this study is to evaluate the performance of a new design of concentrating-type solar cooker using a Scheffler reflector.

The system under study harvests solar energy using a Scheffler dish and focuses it to a flat metal mirror. This mirror reflects the concentrated light under a cast iron slab which is used as a French cooktop. In addition, the system is equipped with an automatic sun tracker.

The performance test took place in Marseille on 17 December 2021 between 11:54 and 14:11 solar time with an intercept area of 6.9 $m^2$. It followed the main guidelines of the standard provided by the ASABE. The experimental procedure consisted of heating 22 kg of water from ambient temperature to 95 $\circ$C. The water temperature, the ambient temperature and the direct normal irradiance were recorded throughout this heating phase. The instant power collected in the water was calculated, normalised by an irradiance of 700 W/$m^2$ and then plotted against the temperature difference between water and air. Finally, a linear regression model was computed from this data. Thus, the standard cooking power obtained with the regression model for a temperature difference of 50 $\circ$C is 628 W. This figure is a measure of the thermal performance of the cooker and allows it to be compared with others.

The results reveal that the standard power is quite small for such a large system. This indicates that there is considerable potential for improvement, although professional cookers are already able to use it. The results also raise questions about the standard procedure, in particular the quantity of water, the number of pots and the estimation of the heat stored/released by an internal heat storage.

**Keywords:** standard test, Scheffler reflector, solar cooker design

*Speaker

# Insect wing expansion

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During its final transformation to morph into its adult form, just after hatching from its pupal case, an insect deploys its wings over just a couple of minutes. The wings unfold rapidly from a wrinkled compact structure to a plane that subsequently solidifies to generate rigidity. We studied wing expansion in Drosophila melanogaster. Expansion is regulated by an increase of the internal pressure and by the injection of a viscous liquid (hemolymph) into a folded deployable structure under hormonal control (Bursicon).

We first characterized the kinematic of the deployment by macroscopic observations. Using light microscopy imaging, we were able to describe the initial origami-like folded wing and how it relates to the final veins network. We then imaged sections of fly wings using transmitted electron microscopy (TEM) to study the morphological evolution of the wing cross-section at different stages of expansion. Micro-CT finally gave more insight into both the 3D structure of the folded wings as well as the internal structure of it. Next, we quantified the fluid pressure, the fluid flow and the elastic properties of the wing. Finally, we combined scaling analysis, numerical simulations and experiments to build a fundamental understanding of the wing expansion dynamic.

**Keywords:** biomechanics, morphogenesis, fluid structure interaction

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# Development of an integrated "Product & Process Monitoring Block" (PPMB) to monitor chip to chip process variabilities on advanced CMOS technologies

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Electronic chips are manufactured by batch, simultaneously, on a silicon slice called "wafer". At the end of the manufacturing process, some tests are realized to check the quality of the produced chips all over the wafer. Indeed, manufacturing variations can cause ("process variability"), can impact die performances (power consumption, frequency...)
Until now, process variabilities could be considered as homogeneous for a given wafer. However, due to transistors size reduction (since 40nm transistors technology), intra-wafer variabilities exist and might not be caught in a mass-production test flow. If so, it would imply to find a compromise between reliability (which need some aggressive margins for tests "go/no go" limits) and yield.
The aim of this subject is to demonstrate that a little hardware block embedded in each die in the wafer can catch these variabilities during the mass production test flow with low test time impact.
The developed block allows the monitoring of two main parameters that are impacted by process variability:

- Frequency of a logic cells circuit implemented as an oscillator.
- Limit frequency for which the output of consecutive NVM reads are correct (performed by a hardware state machine)

First silicon results analysis (40nm technology) evidences that the two blocks manage to catch variabilities. Indeed, after a satisfying analysis of the measurement errors (+/- 1% when several repetitions of a same test), an analysis performed in various environment conditions (Voltages & Temperatures) shows a significant die-to-die dispersion. It can also be noted that for a same die, the dispersion isn't the same between NVM and logic cells.

*Speaker

Analysis is still in progress. Once achieved, results will be used to establish a test strategy that optimize as much as possible yield and reliability at the same time.

**Keywords:** Product process monitoring block

# Deflagration-to-detonation transition of highly reactive mixtures in narrow channels

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The use of hydrogen is often presented as one of the alternatives for carbon-free energy production. However, the particularities of this fuel pose new safety and control challenges. For instance, partially confined spaces, such as the internal structure of a fuel cell, are susceptible to promote deflagration-to-detonation transition (DDT). In addition, the DDT phenomenon, in which a slow combustion wave suddenly turns into a detonation that causes mechanical damage, remains poorly understood. Recent experiments in capillary tubes filled with highly reactive mixtures, such as hydrogen-oxygen, show a new mechanism of DDT in laminar flames whose explanation lacks scientific consensus. We propose the model of an elongated flame to explain the acceleration of the flame tip. In this simple geometrical model, the flame tip is pushed forward by a backflow of burnt gases originating from the flame skirt near the channel walls. This model was validated numerically and experimentally for the first stage of tulip flame formation in narrow channels. Besides, it is known that a critical velocity above which steady flames do not exist appears when observing the solutions of a shock wave generated by a flame. By combining the elongated flame model with the classical analysis of a laminar flame in the limit of high activation energy, we can determine the critical length in terms of the mixture properties. For very energetic mixtures, the critical condition is reached for a flame length of a few channel diameters, while in ordinary mixtures the critical length is too large to be reached within the validity of the model. This may explain why this DDT mechanism has been overlooked in the study of ordinary flames. To validate this mechanism, numerical integration of the reactive Navier-Stokes equations for a one-dimensional flame model is being carried out. A better understanding of this complex phenomenon could help to define more precise safety criteria for hydrogen-based systems, as well as improve the efficiency of future hydrogen-powered engines.

**Keywords:** Deflagration to detonation transition, narrow channels, hydrogen air mixture

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# Study of the mobile granular layer in bedload transport by laminar shearing flow in a tilted channel

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Erosion is a natural phenomenon which moves materials from the Earth's surface thanks to a shearing fluid, and has a significant effect on the morphodynamics of river beds. Following previous work, we investigate experimentally the mobile layer of a granular bed due to a shearing fluid flow, using a refractive index matching technique. The experimental setup consists of a rectangular channel partially filled with particles. We use index-matched combinations of spherical hydrogel particles and a mixture of water, citric acid, sugar, and UCON oil to control the hydrogel particles diameter (which have swelled in the fluid) and the fluid viscosity. The tube is tilted between 20 deg and 45 deg, and we impose an upward fluid flow thanks to a pump, which ensures a stationary regime. Indeed, the upper layers of particles are transported upstream due to the fluid shearing flow, whereas the granular bed tends to slide down due to the gravity. Both particle and fluid velocity profiles are obtained using particle image velocimetry (PIV). The experimental results are compared with a two-phase continuum model having a frictional rheology to describe particle-particle interactions. By varying the viscosity of the fluid, we study the influence of inertia while staying in a laminar regime.

**Keywords:** Granular media, particle/fluid flow, erosion, sediment transport.

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# Forcing method for algebraic hybrid rand/les methods

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The study of turbulent flows is of interest in many fields for safety issues in both natural and industrial situations. In the context of safety studies carried out by the Institut de Radioprotection et de Sûreté Nucléaire (IRSN), an important issue is the risk of deflagration in premises where a source of hydrogen is present as well as in the nuclear reactor containment vessels during a severe accident. In these situations, the turbulent mixing of the different gaseous species plays a determining role in the concentration levels and thus in the risk of ignition and explosion.
The goal of this thesis is to improve the predictions of turbulence models for all applications of the CALIF3S platform developed at IRSN (dispersion, explosion, fire, pollutant transport, ...). As a results, this involves improving the developments carried out for hybrid RANS/LES approaches. These approaches are of growing interest as they improve the predictive performance of RANS approaches while reducing the cost of LES approaches. The main part of the thesis work is based on the development of a volume forcing method and its implementation in a hybrid context for different types of flows (homogeneous turbulence, shear flows, ...) in order to describe as correctly as possible the RANS/LES transition zones. These regions, where the ratio between resolved and modeled turbulent kinetic energy varies strongly, typically correspond either to the zone downstream of the core region of a jet or to the near wall region.
The proposed forcing method was first successfully implemented to sustain isotropic homogeneous turbulence. Secondly, the interest and the limitations of the forcing technique were illustrated on hybrid RANS/LES simulations of a planar jet which is representative of a ventilated room's air outlet. The current work aims to assess the benefits of hybrid methods with forcing on a scaled ventilated room which is the focus of an experimental program conducted at IRSN.

**Keywords:** Turbulence, Hybrid RANS/LES, Forcing method

*Speaker

# Design of mixed system (RRAM memory & digital) targeting binary neural network hardware accelerator

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In this research project, we aim to implement a configurable hardware accelerator for Binary neural networks (BNN) based on Resistive Random Access Memory (RRAM) arrays.
First, we studied the switching speed of the RRAM using an embedded measurement circuit based on write termination. RRAM are characterized by their fast switching speed that cannot be easily measured using conventional measurement solution and requires sophisticated setup. Knowing the switching speed of the memory cell helps to reduce the power consumption during the write operations and increases the lifespan of the RRAM itself.

Secondly, we characterized a hardware implementation of non-configurable BNN accelerator based on RRAM arrays. The hardware accelerator is based on a digital computational block placed near the memory. We studied the functionality of the implemented solution on different frequencies varying from 1MHz to 100MHz. We also studied its power consumption and its energy efficiency using different programming conditions.
Finally, based on the previously tested accelerator architecture, we introduced a configurable solution for BNN implementation. In order to be able to do computations near-memory we introduced capacitors at the bottom of each column of the RRAM array. These capacitors are used to replace the digital circuitry ensuring the multiply and accumulate operation in the characterized solution. The configurability of the accelerator is ensured through analog switches connecting the capacitors together, allowing a high flexibility in the network mapping on the memory array.

**Keywords:** RRAM, Switching Time, Hardware accelerator, BNN, Near, Memory computing

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# Iron snow in planetary interiors: effects of background rotation & particle size on the settling of particle clouds

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Small telluric planets like Mercury or Ganymede – a natural satellite of Jupiter – generate their own magnetic field, likely through dynamo action inside an iron-rich liquid core. The motions generating the dynamo would originate from solid iron snow flakes falling from the periphery to the centre of the liquid core. Understanding the dynamo of such planets requires to model the snow before and during melting (Rückriemen *et al., JGR Planets*, 2015), and to determine whether the collective dynamics of snow flakes can produce a macroscopic flow nourishing the dynamo. Experimentally, we model the snow thanks to spherical glass beads, released with no impulse in still fresh water. This enables to study the turbulence produced by the falling particles, as well as the feedback of turbulence on the particles' trajectories. Photographs are simultaneously taken by two cameras, which enables to perform a Lagrangian tracking of particles, and to quantify the turbulent flow using PIV or LIF. Finally, the setup is mounted on a rotating table to account for planetary rotation on the particles' dynamics. In the canonical framework of Morton *et al.* (*Proc. R. Soc. Lond.,* 1956), the particle clouds' dynamics is studied by performing systematic experiments for one same initial density anomaly, varying two parameters: the radius of particles and the angular velocity of the rotating table. Modifying the radius of particles notably modifies the ratio of particle-to-fluid inertia – the Rouse number – which plays a major role in the clouds' dynamics. In a still environment, the collective settling of particles and their inertial coupling with the fluid contribute to enhancing the entrainment capacity of clouds. Subsequently, the cloud kinematics undergoes a transition as particles decouple from turbulent eddies. Rotation, however, inhibits particulate effects which no longer enhance the entrainment. It introduces a new transition as clouds roll around the vertical axis of rotation and become vortical columnar flows. These transitions separate different regimes of settling which we discuss in our results.

**Keywords:** particle clouds, turbulent entrainment, rotating flows, two, way coupling

*Speaker

# Multiscale modelling of polycrystalline UO2: full-field simulations (FFT) and model-reduction approach (NTFA)

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Uranium dioxide (UO2) is a polycrystalline ceramic used as nuclear fuel within Pressurised Water Reactors (PWR). To account for the behaviour of this material during a Reactivity Initiated Accident (RIA), characterised by macroscopic strain rates (0.1 to 10 (s)-1) and temperatures (T: 500 to 2400 (∘C)), a micro-mechanical approach is adopted. In this study, UO2 is studied above a temperature (T > 1000 (∘C)), which the material exhibits an elasto-viscoplastic behaviour with strain hardening. Assumption is made at the single crystal scale that the viscoplastic strain is entirely induced by the sliding of dislocation lines overcoming the Peierls barrier energy. An empirical thermally activated plasticity law is adopted to model this behaviour with consideration of the strain hardening. An inverse calibration, based on observations made at the single crystal scale, is performed in the aim to determine the numerical values of the parameters composing the evolutions laws. This inverse calibration take into account the sensitivities to the loading parameters (temeprature, macroscopic strain rate). Once validated at the polycrystalline scale on uniaxial compressive strain tests, the full-field FFT numerical simulations are taken as reference to develop and validate a reduced-order model.

This model being used in the future within an industrial code of the fuel rod behaviour, it appeared necessary to use a reduced-order model to obtain reasonable computational costs. The Non-uniform Transformation Field Analysis Tangent Second Order (NTFA-TSO) is used and developed for our study case. The agreements between NTFA-TSO model and full-field simulations (FFT) are checked on the macroscopic responses and local fields on three uniaxial loadings. It is checked that the numerical results of NTFA-TSO model are not deteriorated either macroscopically or locally by using two approaches: strain hardening taken as constant per grain, as in the reference, or decomposed, like the viscoplastic strain, on modes.

**Keywords:** polycrystal, model reduction, elasto, viscoplasticity

*Speaker

# The characterization of CO2 transfer inside a new photobioreactor: the Dinophyt for microalgae dinoflagellate culture

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Microalgae like dinoflagellates are interesting to produce phycotoxins useful as biopesticides, anti-cancer and anti-viral drugs. Unfortunately, conventional photobioreactor using bubbles or rotating blades for CO2 intake and stirring are not compatible with the dinoflagellate culture that are extremely shearing forces sensitive. Additionally, the poor photosynthesis capacities of the dinoflagellates force to compensate this feature by large CO2 quantities intake. The problem is that such CO2 quantities, using bubbling systems create important shearing forces which are detrimental for dinoflagellates. There is currently no technology mastering the culture of dinoflagellate at large scale level, ensuring large CO2 intake, with low shearing forces. Despite their high potential applications, advances in microalgae phycotoxins technology are limited by the lack of material available. In the present study, using a principle of mixing without blades, developed by the Institut de Recherche sur les Phénomènes Hors Equilibre (IRPHE) on a technology called "soft-mixer" combined with a microporous membrane, we succeeded in injecting CO2 into the dinoflagellate culture without bubbles. With this new photobioreactor called Dinophyt, we analyze the flux of CO2 as a function of the Reynolds number and the concentration in CO2. We found the CO2 diffusion is governed by the Ekman boundary layer. This is very helpful to optimize CO2 transfer. Experiments with cultures of dinoflagellates showed greater biomass production and low duplication time compared with literature.

**Keywords:** Rotating flows, Photobioreactor, CO2 transfer, Microalgae culture, Dinoflagellate

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# Modeling and numerical simulation of fluid-structure interaction mechanisms in the aortic valve: An integrated biomechanical model of the aortic valve.

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The aortic root is associated to many heart diseases, and has been a subject of medical research which has been increasing rapidly since the last decade, as evidenced by the growing number of studies and surgical techniques to repair or replace the aortic valve, this aortic valve by a mechanism complex opening / closing based on three sigmoidal cusps.
Review of the literature as well as current surgical practices of tricuspid aortic valve repair shows the need for a better knowledge of its global geometry, both in static (aortic root and aortic valve), and in dynamics (opening and closing of the sigmoid cusps in interaction with the flow).

To progress in the understanding of the biomechanics of the aortic valve, a global approach integrating patient data (DICOM angioscanners), and numerical simulation of unsteady mechanisms of fluid-structure interaction is now necessary. It is in this context, which will be performed between the medical-surgical pediatric and congenital cardiology of the Timone (AP-HM) and the laboratory of Mechanics Modeling (M2P2, UMR CNRS) Aix Marseille University.
A dedicated numerical simulation tool will be used as part of the thesis, based on the numerical methods developed at M2P2 in the context of the numerical simulation of complex geometries immersed in biological fluids (Immersed boundary methods and lattice Boltzmann method). The results of the biomechanical analyzes resulting from this integrated approach will make it possible to better understand the dynamics of the aortic valve, the cardiac pathologies associated with it, and to improve the current operative techniques of surgical repair of the aortic valve.

**Keywords:** aortic valve, immersed boundary, Lattice Boltzmann method

*Speaker

# Multiscale study of UO2 fracture properties

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The nuclear UO2 fuel of Pressurized Water Reactor is a refractory ceramic shaped in the form of pellets. During service, the heat generated by the nuclear reaction is transferred to the coolant by thermal conduction inducing a significant difference of temperature between the pellet core and its periphery. This thermal gradient systematically generates the pellet fracture. In order to study the UO2 fuel behavior numerically, fracture phenomena must be taken into account in the modelling. It is therefore necessary to characterize the fracture properties of this brittle material, which are the strength and the fracture toughness.

A multiscale study of the fracture properties of UO2 is suggested: on the one hand, we aim to analyze numerically the micro-cantilever bending tests, carried out on fresh and irradiated fuel as part of R.Henry's thesis. The main idea is to be able to characterize the geometric defect that caused the fracture initiation using finite element simulations. On the other hand, macroscopic failure comes from the breaking of bonds at the atomic scale. We study therefore the mechanisms of brittle failure at the atomic scale in order to understand the underlying physical mechanisms.

We first propose a finite element modeling of micro-cantilevers bending tests using SALOME and Cast3M. The main goal of this numerical model is to predict the failure force measured experimentally using a cohesive zone model defined by two failure parameters: the critical energy release rate Gc and the critical stress $\sigma c$. A Griffith-based approach allowing the identification of cohesive zone model parameters has been established. Furthermore, methods of atomistic calculations of the critical energy release rate, i.e., the energy required to create new fracture surfaces, are proposed. These methods are based on atomic decohesion processes and energy separation law. Atomistic simulations of tensile tests were carried on, leveraging the molecular dynamics code LAMMPS. Our results allowed us to improve our modelling of separation energy curves.

**Keywords:** multiscale simulations, UO2, failure properties, finite elements, cohesive zone model, atomistic simulation

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# Radiative transfer equation for acoustic waves in half space taking into account the coherence related to the reflections

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Radiative transfer theory was introduced over a century ago to describe the propagation of light in complex media. Today, it is used in many other fields such as geophysics, weather forecasting, and movie scene illumination. However even if its potential has been widely identified its application remains marginal in many engineering fields. One of the reason is related to the importance of boundaries in real structures. The objective of this presentation is to derive a radiative transfer model for the energy density carried by acoustic waves propagating in a half space. We take into account the heterogeneities with the border. For that we extend our problem to the full space using the images method. Our wave extend on the full space is the superposition of two symmetrical waves. Moreover, with the symmetrization of the media, we loose the stationarity. Then we introduce the Wigner transform. At the asymptotic limit the Wigner transform gives us the energetic contribution of the two symmetrical waves and the energetic contribution due to the coherence of the waves. A radiative transfer equation is derived from the energetic contribution of the two symmetrical waves. This equation is the same as in a stationary media due to the mixing properties. The energy contribution due to the coherence of the waves is zero except near the boundary of the same order of the wave length. The main application is to highlight the phenomena of coherent backscattering enhancement in random media bounded.

**Keywords:** Wigner transform, asymptotic limit, radiative transfer, coherence, stationarity

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# DEM approaches and multiscale modeling for Toyoura sand under monotonic and cyclic loading

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As a discrete material, sand exhibits complex behavior when subjected to external loading, showing material anisotropy, non-linear stress-strain response, contraction or dilation depending on the void ratio, and additional plastic strain on a loading-unloading path. The Discrete Element Method (DEM) tracks the dynamic motion of each individual particle defined in terms of mass, shape, and inertia. It reproduces directly these discrete phenomena and can be used as a powerful alternative technique to classical soil constitutive models. Here, we propose two different DEM models for quantitatively simulating the mechanical behavior of Toyoura sand along various monotonous loading paths. The first model adopts spherical particles and compensates for the irregular shapes of Toyoura sand grains by adding an additional rolling resistance stiffness to the classical linear contact model. The second model follows a different strategy whereby rolling stiffness is abandoned in favor of more complex shapes in the form of a few different 3D polyhedrons defined from a 2D micrograph of Toyoura particles. Although it leads to 9-times longer simulations, the polyhedral approach is easier to calibrate regarding the contact parameters. It also enables a more precise description of the microstructure in terms of particle shapes and initial fabric anisotropy. Furthermore, the calibrated DEM model has been used to assess the liquefaction ability of Toyoura sand under seismic loading via multiscale modeling of a 3-D soil column. Where the constitutive response of the material is derived through direct DEM computations on the representative volume element (RVE) attached to each Gauss point in the mesh. This approach allows for adequately simulating the evolution of the material response under monotonic and cyclic loading by using three or four contact parameters instead of several parameters that are difficult to calibrate in the case of classical constitutive models.

**Keywords:** DEM method, Polyhedral particles, Multi, scale modeling, seismic loading.

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# Surfing on turbulence

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Living in a turbulent environment, navigation is a challenging task for motile planktonic organisms (plankters). Yet vertical migration is essential to many of them. For example, copepods (crustaceans that are a critical link in aquatic food webs) move upwards at night to feed in surface waters, and downwards during the day to escape visual predators (Richards et al. 1996, Hadfield et al. 2004). Being equipped with flow sensors, can these plankters use local hydrodynamic cues to migrate faster through turbulence?
To address this question, we consider plankters swimming at constant speed whose goal is to move upwards.
We propose a robust analytic behavior that allows plankters to choose their swimming direction according to local flow velocity gradients. Testing this behavior in 3D simulations of turbulence we show that plankters can "surf" the flow and reach net upwards velocity up to twice their swimming speed.

We assess the expected benefit of (active) orientation control over (passive) bottom-heaviness and show that it is advantageous across a wide range of marine habitats.

**Keywords:** plankton, turbulence, navigation, fluid mechanics

*Speaker

# Oscillatory forcing of viscoelastic fluids using Lattice Boltzmann method

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Viscoelastic fluids are ubiquitous in human body and more generally in nature, and their study has many applications in several industrial sectors, including health, biomedical and pharmacy industry. They play a role in several living system structures, such as the human cardiovascular-pulmonary network, blood and mucus for instance, where they are considered as non-newtonian fluids, exhibiting both viscous and elastic behaviours. Elasticity in these kinds of fluids implies that the stress tensor is calculated based on the strain and deformation history. Due to their complex behavior, simulating numerically the dynamics of these fluids still remains challenging, because of the non-linear character of the equations and the associated numerical instabilities. In this work, we use a numerical framework which consists in solving Navier-Stokes equations coupled to a constitutive equation, namely the Oldroyd-B model. In this model, polymer molecules are considered as two beads connected by a spring surrounded by a viscous fluids. One of the most difficult part of the viscoelastic fluid simulation is to deal with high values of the Weisenberg number. The latter is defined as the elastic force to the viscous force and controls the physics and consequently the stability of the simulations. To overcome numerical instability issues arising for high Weisenberg cases, an integrated lattice Boltzmann and finite difference method is proposed to solve both viscous and elastic parts respectively. The numerical approach is validated on several numerical benchmark test cases, including the Taylor green vortex, four-roll mill, Poiseuille flow, and two-dimensional flow past a cylinder. The results present a good agreement with analytical solutions and literature reference data. In this study, we provide a physical analysis of the dynamics of viscoelastic fluid flows forced by an oscillatory Womersley flow, in the context of mucus clearance in human respiratory system. The results show that the highest flow rate of mucus can be achieved in the case of resonance, i.e. when the frequency of the Womersley flow matches the natural frequency of the viscoelastic fluids. Increasing the elasticity of the fluid is found to increase the mucus flow rate. These results are meaningful in the context of biomedical devices improving mucus clearance of bronchial mucus patients suffering from chronic respiratory diseases associated to mucus transport dysfunction such as asthma or COPD.

**Keywords:** Viscoelastic fluid flows, Oldroyd, B, Lattice Boltzmann method

*Speaker

# Hydrogen sensor for anaerobic measurement based on a PdAu thin layer

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**Hydrogen is a promising gas for greenhouse gas emission but also a reactive one. Thus, sensors for hydrogen detection in various atmospheres is mandatory. While leak sensors in air environments have been widely studied, only few researches have been done for hydrogen detection in anaerobic environments. Palladium is a metal that interact reversibly with hydrogen by absorbing or desorbing it depending on pressure fluctuations, but there are evidences of a fast ageing process. The addition of gold stabilizes the structure and improves sensor performances. In this work, the electrical resistance variation of a PdAu alloy as a sensitive film is studied at various temperatures for hydrogen exposures in anaerobic environments. The Pd0.8Au0.2 alloy was deposited on a Si/SiO2 substrate using magnetron sputtering followed by annealing at 200◦C in N2. The sensor was then tested at various temperatures for 0.3% H2 exposure; the best operating temperature was found to be 50◦C. Finally, sensor was able to detect at 50◦C, concentrations from 0.3 to 3% H2. These preliminary results are promising for further development of hydrogen sensors in anaerobic environment.**

**Keywords:** Hydrogen, PdAu, Resistive sensor, Anaerobic environments

*Speaker

# Finite-size effect for object penetration in granular media

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In many industrial or geotechnical applications, objects are moving in a granular media and an important question is the prediction of the resistance force that develops during the motion of the intruder. One configuration of interest in digging process is the vertical penetration, which has been investigated in many studies. Scaling laws have been evidenced showing that the vertical force when a cylinder is indenting a granular media varies linearly with the penetration depth z, and is proportional to the section S of the cylinder : F = K $\rho$ g S z, where $\rho$ is the particle density and g the gravity intensity.
Here, we investigate a regime encountered in some application when digging in a coarse granular media, when the intruder size is close to the grain size. The experiments consist in measuring the time evolution of the force during penetration. Two different regimes are identified depending on the ratio between the cylinder size D and the particle diameter d. For large aspect ratio A = D/d, the coefficient K is constant whereas for small aspect ratio a finite size effect is observed and K significantly increases. This shows that it is more difficult to penetrate a coarse material than a fine one. We also analysed the force fluctuations and show that the fluctuations amplitude decreases when increasing the aspect ratio and follow a power law. Finally, the influence of a conical tip at the head of the cylinder is studied. We found that a tip facilitates the penetration only at low aspect ratio when finite size effects are significant.

**Keywords:** Granular flows, finite size effect, object particle interaction

*Speaker

# Modelling tension driven phase separation on T cell plasma membrane

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T cells are critical components of the adaptive immune system which play a crucial role in viral infections and cancer. Researchers have been long searching for a better understanding of how a T cell functions and particularly how it is activated. Upon activation by the interaction with an antigenic ligand, the T cell plasma membrane undergoes a rapid change in which the liquid-liquid phase separation of the membrane-bound signalling molecules occur at the immune synapse which is strongly correlated to the change in membrane topography. This change is triggered by the action of actin cytoskeleton whose remodelling at the synapse is well described. We use a continuum mechanical model for the T cell to study this coupled effect of phase separation and topography change in which the surface is discretized using the finite element method. Our hypothesis is that the local change in membrane tension induced by the cytoskeleton activation drives the phase separation. Our hypothesis is supported by the fact that liquid-liquid phase separation occurs at the synapse, a site of strong actin remodelling, and that we detected that the resulting molecular condensates accumulates in synaptic regions with low actin content. A membrane model for T cell which resembles close to the reality is made and will be tested by comparing with the actual biological system. Additionally, a cytoskeleton will be added to understand the effect of local membrane tension. Different materialistic behavioural laws for both the plasma membrane and the cytoskeleton is compared. The phase separation of the signalling molecules is modelled using the surface Cahn-Hilliard equation in which the critical temperature is made to be a function of the local tension. To study the effect of cytoskeleton, a much simpler Red Blood Cell model in shear flow is used, and the modelled cytoskeleton will be extended to the T cell in later stage.

**Keywords:** Continuum mechanics, T cell, Phase separation

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# Transposition to a large scale of an ultrasonic NDT method for concrete - nonlinear tomography of a massive block on the ODE experimental platform

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Internal Swelling Reactions (ISR's) are pathologies that can lead to expansion and, consequently, a progressive cracking of concrete, reducing the durability of structures. In order to predict and monitoring these pathologies, it is essential to implement systems able to detect early the occurrence of these pathologies *in situ*, to characterize and localize them.
For nuclear power plants, reinforced concrete and pre-stressed concrete constitute the containment wall. This structure is the third barrier of confinement and mechanical protection against external agressions. For this reason, the development of non-destructive testing (NDT) techniques is essential for monitoring in-service within the context of an service life extension, currently planned by the operator to 60 years.
The latest studies, within the PhD thesis LMA/IRSN of Florian OUVRIER-BUFFET (2016-2019), have demonstrated, on an intermediary scale, the effectiveness of NDT, to detect areas with non linear properties. Based on a propagative pump wave with low frequency vibration to generate the nonlinear behavior and on a probe wave to auscultate the concrete, the NDT allows to image the state of the concrete heart.
The present thesis is being developed at the LMA in cooperation with IRSN and will be based on previous laboratory tests, to validate this NDT in laboratory and translate it to the in situ scale. The aims is to optimize the early detection of the presence of internal swelling reactions (Alkali Aggregate Reaction in priority) on large blocks of 1 m thickness. The work will extend on the aspects of waves focalization to auscultate the containment walls and extract a 3D tomography of the non linear properties linked to the pathology.

**Keywords:** Alkali, Aggregate Reaction, Non, destructive Testing, Ultrasonic, Concrete, Swelling Pathologies

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# Local instabilities of thin plates by geometrical confinement

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When a thin plate is submitted to compressive stress it can experience buckling instabilities and deform out of its plane .
However, it is possible to induce more complex patterns by adding geometrical constraints.
Our study focus on the emergence of localized deformation caused by a geometrical confinement of thin elastic disks.
We use an elastic disk pushed into a hollow cylinder by an indenter. With this set-up, we observe three distinct deformation regimes: an axisymmetric state, followed by an orthoradial buckling regime , and a d-cone.
Using experimental measurement and a non-linear plate model based on the Föppl-von Karman equations, we identify and characterize the transition between these states, controlled by two parameters : the aspect ratio between cylinder and disk radius alpha, and the dimensionless indenter depth delta. Thèse dirigée par : Marc Georgelin, Julien Deschamps et Gwenn Boëdec

**Keywords:** Elastic behavior, Plate instabilities, Geometrical confinement.

*Speaker

# Lattice-Boltzmann modeling of buoyancy-driven turbulent flows

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The pressure-based hybrid lattice-Boltzmann method presented by Farag & al in Phys. Fluids, vol. 32, p. 066106 (2020) is assessed for the simulation of buoyancy driven flows. The model is first validated on Rayleigh-Benard and Rayleigh-Taylor two-dimensional cases. Followed by a three-dimensional large-eddy simulation of a turbulent forced plume, the results are validated against experiments. A good overall agreement is obtained, both for mean and fluctuations quantities, as well as global plume quantities and fluid entrainment. The self-similarity characteristic of the plume in the far-field is also recovered.

**Keywords:** Large eddy simulation, Turbulent flows, Buoyancy driven flows, Lattice Boltzmann Method

*Speaker

# Microwave antennas in printed technology.

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Embedded systems integrate more and more connectivity solutions, particularly since the development of 5G. They are generally composed of multiple components, sensors, memories, and antennas, derived from years of research. These components are designed, built, and integrated in these systems following high performance constraints. To meet the high-performance requirements of today's embedded systems and to meet the demands of large numbers of users, efficient and cost-effective processes need to be achieved. The development of printed electronics is envisaged as a production solution by research and industry. The main challenge is to develop low-cost solutions that ensure a sufficient level of performance for integrating components into the next generation of embedded systems.
As part of the thesis, we concentrate one of the methods of production of printed electronics: Screen-printing. Screen printing is a printing process for electronic, by deposition of conductive ink on a material to design the desired pattern. This method significantly shortens production time and prevents unnecessary use of materials. The thesis studies focus on the performance of screen printing for multiple telecom applications. This study is based on a comparison of screen-printing performance with other industry standard production processes.
We design a large variety of antennas with various properties to analyse and compare screen printing performance. The study of mono-band antennas, multi-band antennas, or "ultra-wideband" antennas, combined with various polarization methods and innovative materials provides a comprehensive overview of screen-printing performance and conclusions for the manufacturing of antenna devices.

**Keywords:** Antenna, printed electronics, screen, printing, innovative materials

*Speaker

# Lattice Boltzmann method and heat transfer problem

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This research proposes two numerical strategies based on Lattice Boltzmann method (LBM) to solve the heat transfer problems. The numerical approach in fluid dynamics, i.e., computational fluid dynamics (CFD) has progressed rapidly during the last several decades and has fundamentally changed the industrial design process. Contrary to the classical Finite Difference (FD) or Finite Volume (FV) methods solving the partial differential equations of fluid dynamics, i.e., Navier-Stokes equations, a more advanced and innovative numerical method - Lattice Boltzmann method (LBM) receives more attentions nowadays because of various outstanding advantages such as ease of implementation, parallel nature, high computational efficiency etc. Recent three decades have witnessed the great growth and revolutionary progress of LBM with its capabilities extended to subsonic and supersonic flow, high Reynolds number turbulent flow, combustion, heat transfer and other multi-physical configurations. However, the heat transfer problem which is encountered frequently in realistic industrial applications such as turbo-machinery, combustion, cooling system of aeronautical and automobile devices remains challenge, especially when large temperature difference and strong thermal conductive effects are present. In this study, a pressure-based LB method corresponding the fully compressible Navier-Stokes system is adopted to simulate heat dominated flow. Then a novel hybrid LB algorithm in low-Mach number approximation (LMNA) is proposed to increase the computational efficiency at low Mach regime. A various well-documented physical configurations including 2D natural convection, three-dimensional (3D) Taylor Green Vortex and 3D heated cylinder at Reynolds number Re=3900 are adopted for the validation. Promising results with high accuracy is obtained by the pressure-based LB method which demonstrates its capacity on simulating heat-dominated flow without the limit of Mach number. At least ten times speed-up is achieved by the low-Mach LB method while maintaining great precision.

**Keywords:** LBM, heat transfer, pressure, based, LMNA

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# Lattice Botlzmann method applied in wind turbine wake study considering the influence of atmospheric stability

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Lattice Boltzmann method(LBM) is an efficient alternative approach to traditional Navier-Stokes, however it is seldom applied in wind engineering, especially research of wind farm under realistic atmospheric boundary layer(ABL). In this study, the atmospheric thermal stratification influence on wind turbine wakes is investigated by using the large eddy simulation (LES) combined with the Lattice Boltzmann method. First, the actuator line model is used to parameterize the body forces of wind turbine on the flow field, which is validated under uniform inflow regard the blade quantities and wake velocity deficit. Moreover, synthetic eddy method is applied at the inlet to consider the different velocity and Reynold stress of stable, neutral and convective atmospheric boundary layer, which is modeled based on the Monin-Obukhov similarity. The wake recovery speed and wake profile characters is well captured under different thermal boundary layer, which reveal the significant influence of thermal effect on the wake behavior. Above all, the LBM-LES approach is applicable for simulation of single wind turbine under ABL, which could be beneficial for further study of wind farm interaction with ABL.

**Keywords:** atmospheric boundary stability, wind turbine, Large eddy simulation, Lattice Boltzmann method

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# Development of a transdermal ammonia mesoporous microsensor based on copper bromide sensitive material for chronic kidney disease monitoring

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Chronical kidney disease (CKD) alters the kidney function of acid load regulation. The main consequence is metabolic acidosis leading the progression of CKD to the need for dialysis or kidney transplantation. The acid load is mainly provided by the breakdown of proteins consumed daily. The main solute produced by the kidney to eliminate acid load is ammonia. The need for blood samples and the inaccuracy of urinary analysis limit the guidance that we can provide to patients regarding their diets. Thus, the development of innovative, rapid, non-invasive, and low-cost tools is critical.
It has been shown that part of ammonia can be eliminated through the skin and can be used as acid load bioindicator. Our work aims to develop a microsensor to detect selectively transdermal ammonia with very high sensitivity (_˜20ppb). The detection is based on the resistance variation of the sensitive layer in the presence of target gas. For miniaturization, portability and device's cost reduction, the sensor should operate at room temperature.

The innovative aspect relies on the development of a microsensor based on a novel material combining both a mesoporous matrix elaborated by sol-gel method and copper bromide. The mesoporosity of the sensitive layer offers a large specific surface which favors the sensitivity. The copper bromide is an ionic conductor which interacts with ammonia and allows to detect the gas selectively. Sensitive layers were deposed by dip coating on interdigitated electrodes and tested under ammonia. The first results demonstrated the sensor performances at room temperature until 300 ppb of ammonia. The responses are reversible and repeatability error is small.
In the near future, the performances of the sensor will be validated on a test bench under various atmospheric conditions and will be tested on volunteer subjects in collaboration with the Centre of nephology and renal transplantation in Marseille.

**Keywords:** Chronical Kidney Disease, Copper bromide, Mesoporous microsensor, Ammonia microsensor

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# Spin Transfer Torque MRAM characterization

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A new experimental technique for measuring the switching dynamics and extracting the energy consumption of Spin Transfer Torque MRAM (STT-MRAM) device is presented. This technique is performed by a real-time current reading while a pulsed bias is applied. The switching from a high resistive state, anti-parallel (AP) alignment, to a low resistive state, parallel (P) alignment, is investigated.Increasing the applied voltage leads to a higher spin torque on the free layer in a shorter time. This decreases the time needed to change the magnetization orientation of this layer, thus the time required before the switching occurs. A set of measurements is carried out operating at different applied voltages and temperatures ranging from 25○C to 90○C. As main results of our analysis, we show the decrease of the preswitching time with temperature increase. The Arrhenius law enables the extraction of the activation energy required to switch the cell in both states. Finally, we establish the relevant state transition probabilities using the Weibull distribution that best fits our results. The Weibull parameters highlight the preswitching time stochasticity and the variability of the switching characteristics of the STT-MRAM device, useful in high reliability applications.

**Keywords:** Magnetic switching, MRAM devices, perpendicular magnetic tunnel junction, spin transfer torque.

*Speaker

# Experimental Study of soil's resistance to surface erosion using HET and EFA

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Erosion in earthen hydraulic structures such as dams and dikes is a major issue nowadays, given the material and human damage it causes (1). Studies have shown that almost half of failures in embankment dams is due to surface erosion, i.e. erosion generated by a tangential flow along a soil surface (2). The susceptibility of hydraulic earthworks to surface erosion depends on the nature and properties of soils *(3,4)*.
In the present work, a series of erosion tests have been carried out, in laboratory, using two different experimental devices: Hole Erosion Test (HET) *(5,6)* and Erosion Function Apparatus (EFA) *(7,8)*. In both cases, these devices involve a water flow in charge along a pipe. The difference between them lies in the geometry of the soil/water interface as well as in the hydraulic radius of the flow and its possible evolution during the test.

The scientific purpose aims to study the reproducibility of both devices as well as to investigate the influence of several soil's parameters, namely water content, coarse grain shape, compaction degree and clay mass fraction, on the resistance of cohesive soils to surface erosion. To this end, many tests have been conducted on different mixtures of fine material (Armoricaine Kaolinite) and coarse grain material (Hostun sand, Loire sand, and glass beads).

The results of both HET and EFA are found reasonably well reproducible under identical test conditions. The results also reveal that erodibility does not clearly correlate with soil water content. However, the increase of clay content in soil mixture or the increase of soil's density strengthens the erosion resistance of our cohesive soils. As regards coarse grain shape, our findings indicate that rounded particles ensure a better resistance against the initiation of erosion but once the erosion has started, they promote a higher rate of soil removal.

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**Keywords:** Internal erosion, experimental study, hole erosion test, erosion function apparatus, soil mixtures.

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