GEEPS - UMR 8507

GROUP OF ELECTRICAL ENGINEERING – PARIS

The laboratory GeePs is a joint unit of CentraleSupélec, Université Paris-Saclay, Sorbonne Université and CNRS. It is located on two sites: the CentraleSupélec campus of the Paris-Saclay University in Gif-sur-Yvette and the Pierre & Marie Curie campus of the Sorbonne University in Paris.

With more than 250 collaborators, consisting of 127 permanent staff (researchers, lecturer-researchers, engineers, technicians and administrates), about 70 PhD students, numerous visiting scholars and trainees, it is one of the most important laboratories in the field of "Electrical Engineering" in the "Ile de France" region.

The research conducted in the laboratory combines a three-pronged approach: theory – numerical modeling - experimental characterization / validation. It is distributed over **three research departments** that assure a continuum of activities that extend from materials to electronic or energy conversion systems.

The research activities are supported by **two transverse centers of expertise**. The first center capitalizes the historical competence of the laboratory in numerical modeling of electromagnetic systems with an orientation towards multiphysics and coupled problems on the one hand, and the complex electromagnetic environment on the other hand. The second gathers together the numerous experimental platforms of the laboratory with the primary objective of pooling together instrumentation skills and sharing know-how and resources.

The three departments and the two expertise centers interact through **thirteen themes** (research groups) whose activities address five major societal issues as shown in figure next page.

MATERIALS: PHYSICS & COMPONENTS

In the "Materials" department, we are interested in new materials for applications in the field of electronics and electrical energy, for better efficiency, lower cost, or to avoid toxicity problems, or to achieve better stability and offer more outstanding durability.

We study the fundamental aspects of materials, their electrical properties, but also physical or physico-chemical properties, mechanical, magnetic, ferroelectric, piezoelectric aspects, along with multiphysical couplings. These studies extend to the operation and properties of components made from these materials, which can be integrated into systems. We develop original characterization platforms and techniques, as well as adapted numerical modeling.

Our main application areas are in the themes: Photovoltaics, Nanoelectronics, Electrical Contacts and Connecting Devices, Power Electronics and Sensors and Functional Materials.

ELECTRONICS: WAVES, COMPONENTS, SYSTEMS

The electronics department aims to address the societal challenges defined within the GeePs' scientific project, by offering a wide range of solutions and methods in the field of hardware information processing.

To this end, it is developing a strategy promoting transversality and studies at interfaces, and conducting research in close connection with the industrial partners and the academic world on a national and international level. It focuses its activities around:

- Ultra-low power consumption, miniaturization and reliability of integrated circuits and systems (autonomy of connected objects, bio-sensors)
- Control of the generation, propagation and detection of electromagnetic waves (detection, localization and focusing of energy and information)
- Multiphysical coupling of functional materials (energy transfer and energy harvesting)
- Electromagnetic control of complex media and CEM (modeling and inverse problem)

The Electronics Department, structured around five themes, three of which are cross-cutting, has strong skills in the field of integrated electronics, electromagnetic waves and sensors.

For all of these activities, Electronics Department relies on significant hardware and software resources embodied by the two centers of expertise of GeePs.

ENERGY – COMPONENTS, CONVERSION AND SYSTEMS

Electrical energy systems have to fit into a context of energy decarbonization, which places electricity as a key vector for the exploitation of renewable energies, and into a process of massive electrification of uses. Whether in land or air transport, in energy distribution, or in certain

sectors such as health and well-being, equipment must satisfy constraints of reliability, energy efficiency, compactness and flexibility. In embedded applications, higher levels of integration bring components physically closer together, and increase the complexity of system behavior through new couplings and interactions.

The "Energy" department aims to design, model, control and optimize electrical and electronic energy systems in order to broaden the fields of use of these systems (more electric aircraft, carbon-free vehicles, smart-grids, biomedical applications, etc.) by meeting the challenges arising from the constraints on applications.

Among these, we note:

- Improving energy efficiency and performance (in particular through system design and control),
- Integration (compactness, miniaturization...),
- Reductions of mass and cost,
- Improving reliability (in diagnosis, detection, protection, ...).

Research groups address 5 major themes:

- Actuation,
- Power Electronics,
- Transmission and Distribution Electricity Networks,
- Electrostatic, Electrical discharges, Arcs, Plasma Processes.

THE TWO EXPERTISE CENTRES

Electromagnetic and Multiphysical Modeling

The Expertise Centre "Electromagnetic and Multiphysics Modeling" results from a historical expertise and a significant role played by the laboratory in developing of numerical models and simulation tools in Electrical Engineering. This is supported by over twenty modeling servers run by the department with access to the *CentraleSupélec Mesocentre* computing platform providing computing power, and electrical engineering and multiphysics modeling software both in-house and commercial.

This expertise is connected to various research subjects carried out within the different groups in GeePs. Researchers develop their own original dedicated modeling approaches, open source tools, or even exploit cutting edge commercial software. An important target of the Expertise Center concerns the dissemination of know-how.

The objectives are as follows:

1. Maintain and disseminate the expertise related to modeling and numerical methods. Promote modeling / simulation tools between the different groups of GeePs. To this end, the center organizes scientific meetings or discussions for better dissemination of skills around modeling methods and software.

2. Set up Master level scientific animation courses/ internships related to electromagnetic and multi-physics modeling in connection with the research topics of the laboratory.

3. Identify, share, and optimize computing resources within the constituent research groups and the different sites in coordination with the CRI (the digital resource center), and promote local communication and remote access to simulation tools via the expertise center.

Characterization Instrumentation Platforms

The disciplinary fields of the GeePs, which range from materials physics to component and systems engineering. In each of its domain of expertise, a recognized and solid know-how in both material and electrical characterization has been acquired over time. Through its research activities, the laboratory has a long history, and the skills, in the development of original instrumental devices to extend its experimental analysis capabilities. When appropriate, those devices can be commercialized. The GeePs has also invested in high end, specialized, complementary equipments assuring its leading position locally and nationally.

The expertise center has the mission of supervising the experimental platforms and its equipments. Its main objectives are focused on:

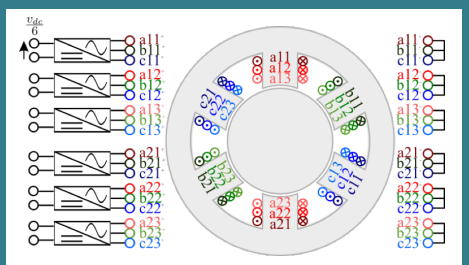
- The identification of equipment, expertise, and instrumental developments in order to facilitate the provision of equipment,
- The promotion of internal know-how,
- The listing of equipments, instrumental developments, and software requirements to set up training and funding actions following the scientific orientations of the laboratory's themes,
- The communication on our technical resource and expertise in order to stimulate the use of specific equipments for service providing,
- Setup price list for internal and external provision of service.

HIGHLIGHTS 2023

- **Frédéric Reymond-Laruina** received the Thesis prize IEEE PES France 2023.
- **Vincent Andraud** was awarded the *Prix de thèse Ampère-SEE 2023* by the *Société de l'électricité et de l'électronique*.

- **Alexandre Bach** received the Best presentation prize symposium SATES 2023.
- **Vladimir Pineda-Bonilla** was awarded the *Roland Coehlo prize* for the best poster presentation for his poster entitled *Analysis of the effects of partial discharges in a power cable for aeronautical use*).

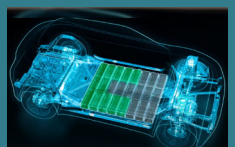
- **Fractional Power Supply drive train (CTAF)**
The patented CTAF concept enables us to rethink the structure of drive trains, including power electronics, control and the electric machine, by extending the principle of fractioning this assembly to a level well beyond the most recent achievements. The new concept makes for a much more flexible combination of source(s) and machine(s), with additional degrees of freedom to enable a true optimization continuum and resilient, potentially multi-source operation (GeePs/ SATIE cooperation).



Principle and realization of the fractioning of a motorization chain

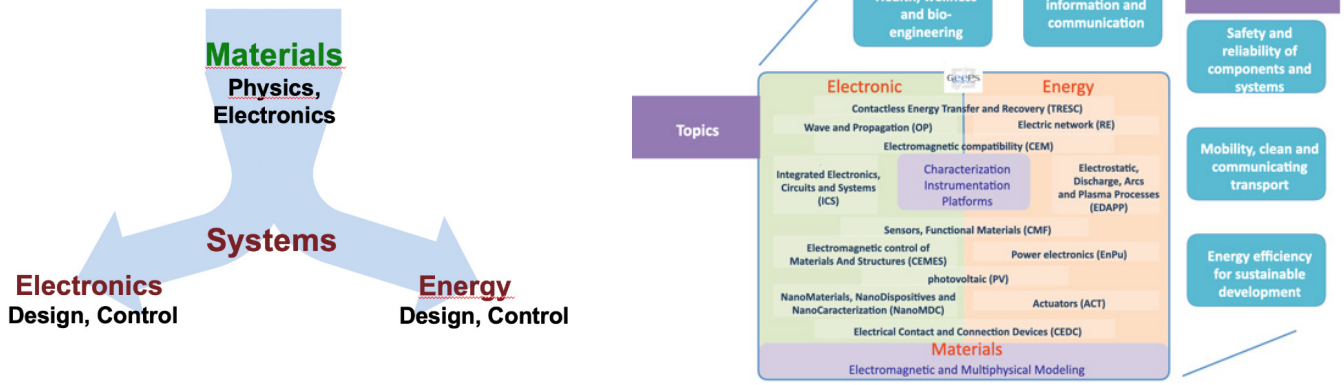
- **Intelligent Battery Integrated System (IBIS)**
After four years of design, modeling and simulation, a team of twenty-five engineers and researchers from CNRS, Stellantis and Saft unveiled on 20 July 2023 an innovative prototype energy storage battery that integrates the functions of inverter and charger. This integration makes it possible to create a battery that is more efficient, more reliable and less expensive. For electric vehicles, it frees up space and improves range. In the field of stationary energy storage and renewable energy integration, the IBIS concept offers turnkey installations with improved availability, optimized use of installed energy and a smaller footprint.

The IBIS project is funded by the *Plan d'Investissement du Futur* (France 2030), administered by ADEME (Agence de gestion de l'environnement et de l'énergie) and coordinated by Stellantis. It brings together industrial partners Saft (TotalEnergies Group), E2CAD and Sherpa Engineering, as well as three CNRS research laboratories (GeePs, SATIE, LEPMI) and the Lafayette Institute.

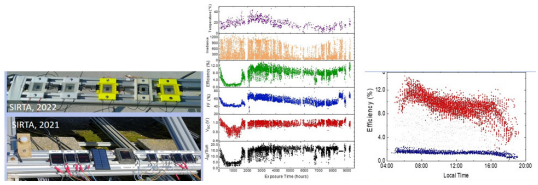


Three phase power generation

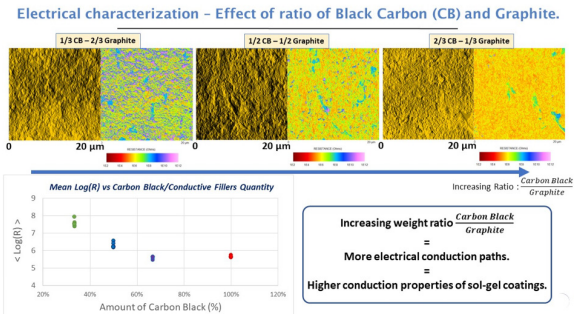
Renewable energy plant with stationary storage batteries



Organization of the laboratory



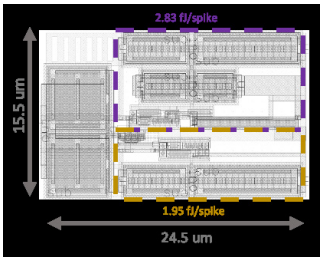
PV platforms at SIRTA and long-term evolution of the output PV parameters of perovskite solar cells



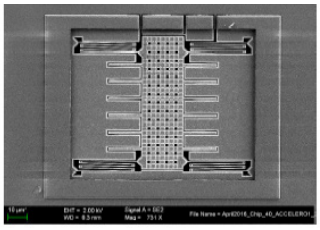
Characterization by conductive probe AFM (Résiscope) of sol-gel coatings with two types of fillers (carbon black and graphite) for conducting properties. Sol-gel coatings with three different compositions are shown here. For each image : topography on the left and electrical resistance on the right (J. Acquadro PhD).

Infrared detector array based on amorphous semiconductor Y-Ba-Cu-O in its integrated circuit package mounted on a test printed circuit board. Technology in collaboration with C2N.

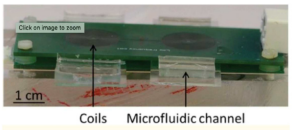
Materials: Physics & Components department



New design of ultra-low power neuro-inspired device



Micro electronic design for vibratory energy harvesting



Lab-on-chip, detection of biological agents

Micro-Transducer for remote supply

Data and Energy focusing: antenna arrays and metasurface antenna

Electronics: Waves, Components, Systems Department

Installation of the Turning Sun into Water project

Test bench 15000 rpm 60 kW

Energy – components, conversion and systems Department

Industrial Partners

- Airbus Helicopters
- Amphénol Socapex
- CEA
- CETIM
- DGA
- EDF
- EFI Automotive
- FORVIA
- IFP Energies Nouvelles
- Nidec Corporation,
- ONERA
- Quantom
- Renault
- RTE
- Safran
- SNCF
- Stellantis
- Thales,
- Valeo
- ITE IPVF
- ITE VeDeCom
- SuperGrid Institute
- IRT SystemX
- IRT Saint-Exupéry

Academic Partners

L2S, C2N, Esycom, ESTACA, LMD, LPGP, LMPS, SATIE, LIMSI, XLIM, IMN, ICMMO, LSPM, Inst. Fresnel, IRDL, GScop, Hôpital Marie Lannelongue, GdRs SEEDS / Ondes / SOC2, FedPV, GDRi Sinergie, ELyT-Max, Texas University, Politechnico Turin, Univ. Patras, Univ. Rep. Paraguay, Univ. JiaoTong Xi'An, Univ. Rabat, Nanyang Technological University of Singapore, LRI 3288 CINTRA (Singapore), KEK Tsukuba (Japon), Chang Gung University (Taiwan), Chulalongkorn University (Thailand), UFSC (Universidade Federal de Santa Catarina), Aalto (Finland).

Key figures

• Professors, Associate Professors & Researchers	96
• Engineers & Administrative staff	31
• PhD Students	68
• PostDocs	18
• Visiting Professors	8
• Publications of the year (WoS)	114

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