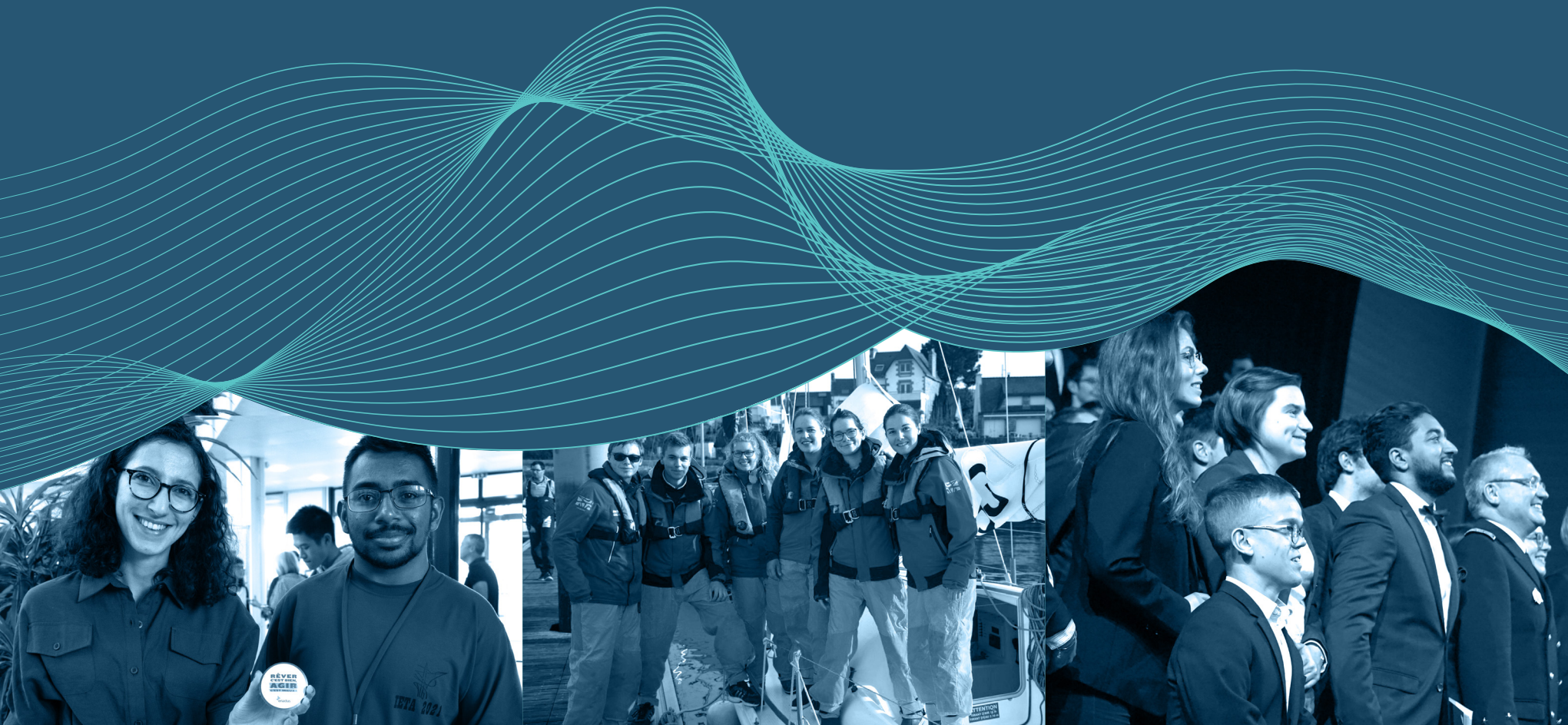




**ENSTA
BRETAGNE**

SCIENTIFIC REVIEW 2019





RESEARCH

RESEARCH

The research activities led at ENSTA Bretagne are in response to concrete military and civilian issues and questions asked by industries or the DGA.

The development of structured relations with the major historic industrial partners, Naval Group and Thales, continued in 2019: the renewal or creation of joint laboratories with Naval Group, Gustave Zédé [dedicated to the sizing methods of marine structures] and SENI [dedicated to the naval embedded intelligence systems]; the creation and launch of the TRANSNUM chair, in partnership with Thales DMS, and including ISEN Yncréa Ouest, dedicated to the use of digital technologies for the security of maritime spaces. Finally, ENSTA Bretagne has joined the naval systems cyberdefense chair, led by the Ecole Navale, IMT Atlantique, Naval Group and Thales.

The school's research institute has expanded: a 1,600 m² building dedicated to the activities in mechanical sciences of the Institut de Recherche Dupuy de Lôme (IRDLD) [Dupuy de Lôme Research Institute], has been built, and the building containing the cybersecurity activities has been refurbished. These constructions are part of the Plan Etat Région [state regional development plan] [CPER] 2015-2020 and thus house the new experimental facilities belonging to 5 investment programs [EcoSYsMer, CyberSSI, SMDMar, IROMI, Sophie], financed by the Breton territorial community, the French Ministry of Armed Forces and the European Union.

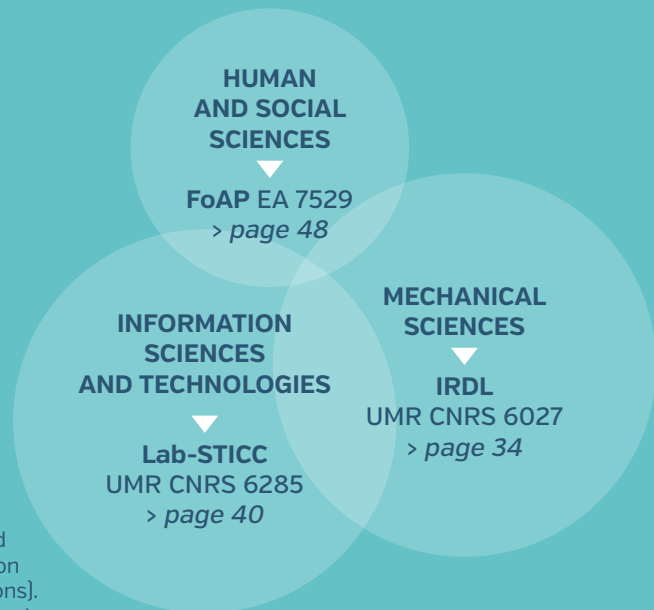
116
THESES
IN PROGRESS,
DEFENDED
AND STARTED

CONTRACTS WORTH
9,95 M€
NOTIFIED IN 2019

The year has again shown a healthy level of contracts and scientific production [through publications]. The attractiveness and reputation of the school are continuing to grow as demonstrated by the great quality of the new in-take of research professors this year.

Finally, the research activities in human sciences have reached a major landmark this year with the birth of the new "Professional Apprenticeship and Training" research unit in January 2019 under the supervision of the CNAM Paris, AgroSup Dijon and ENSTA Bretagne. One of our professors has been entrusted with its management. In this field, the school has been involved in projects on an international scale, training engineers and innovators who are responsible and aware of major societal challenges.

Our socio-economic environment and the local and regional areas can rely on the numerous fields of expertise of ENSTA Bretagne to prepare the industrial and technological infrastructure of tomorrow, in particular in the field of marine sciences and technologies. The school is contributing to the 70.8 permanent exhibition at the Capucins, and will be its ambassador to a wide public audience.



228
RESEARCH STAFF
AND DOCTORAL STUDENTS



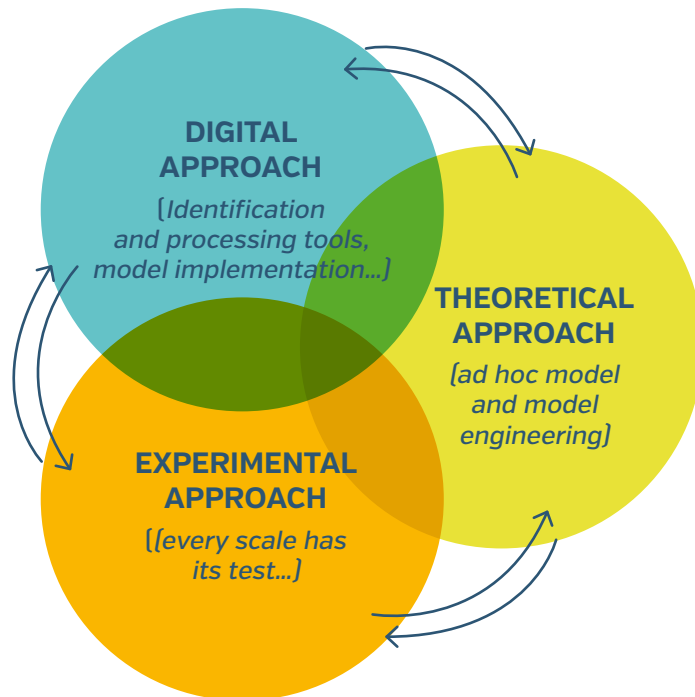
Yann Dautreleau
 Scientific Director

Mechanical
Sciences
UMR 6027

IRDL JOINT RESEARCH UNIT (UMR CNRS 6027)

PROFILE

- Created on 1 January 2016, the IRDL is a mechanical science laboratory of scientific excellence and international and national renown.
- The result of the merger of well-known laboratories, it unites the research teams of 2 universities and 2 graduate schools : UBS, UBO, ENSTA Bretagne and ENIB.
- It is a CNRS joint research unit (UMR 6027), belonging to the INSIS.
- **260** members, including 120 doctoral students.
- Approximately **200** publications in peer-reviewed international journals/year.
- **The leading Breton laboratory in terms of proportion and volume of industry-linked theses** (cf. DRRT Report 2018: 30% of doctoral students under a CIFRE2 contract with a company).
-  irdl.fr



ENSTA Bretagne
is the 2nd most prolific
contributor to the IRDL. "



24
PEER-REVIEWED
PUBLICATIONS



48
THESES SUPERVISED



4,2 M€
NOTIFIED
CONTRACTS

(IRDL figures/ ENSTA Bretagne site)

IRDL SCIENTIFIC PROJECT

Materials and Mechanical Systems Engineering.

The IRDL is appreciated for its ambitious and original scientific project, the good balance between its preliminary and applied studies, the numerous interactions with companies and the quality of its training through research.

The UMR is organized in **5 Key Research Clusters**:

- PTR1 : Composites, nanocomposites, biocomposites.
- PTR2 : Multi-Material Assemblies.
- PTR3 : Structures, Fluids and Interactions.
- PTR4 : Energetic Systems and Thermal Processes.
- PTR5 : Behavior and Durability of Heterogeneous Materials.

ENSTA Bretagne mainly contributes to clusters 2, 3 and 5 and to a lesser extent, to cluster 1.

3 transversal axes, each attached to an industrial sector, are favored and confer upon the IRDL its unique position in France.

- SEA : offshore, naval construction, MREs.
- TRANSPORT : automobile, aeronautics
- DEFENSE : naval, land.

CONTACT

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The Association Française de Mécanique praised the quality of the organization of the 2019 CFM, its impressive program, the originality of its maritime themed sessions, the quality of the reception by the Brest teams and the great success in terms of participation, which made it one of the best ever editions that the CFM had ever seen "

Read the full article
www.campusmer.fr/Actualités-3249-51-0-0.html



MEMORABLE MOMENTS OF 2019

BREST HOSTS THE FRENCH CONGRESS ON MECHANICS IN AUGUST 2019

The IRDL was chosen by the Association Française de Mécanique (AFM) to organize the 24TH edition of the Congrès Français de Mécanique or French Congress on Mechanics, from 26 to 30 August. Several thousand researchers and scientists met in Brest for this much awaited Biennial.

Juliette Rimetz from Campus Mondial de la Mer was there and tells us about it...

Covering all aspects of mechanics and highlighting major innovations

The CFM is the occasion for keeping up-to-date with research on the mechanics of fluids and solids, mechanical, electronic and engineering applications in materials and even acoustics. "In each research field, there are major innovations" points out Sylvain Calloch, Deputy Director of the IRDL. For example, in the digital field, models are becoming more streamlined. "Computational power is increasing year on year but we have so many data, we do not know what to do with them", explains the researcher. "Model streamlining enables more accurate results to be obtained".

Another example is experimental mechanics: it produces field measurements using optical or infrared cameras. "That changes our way of conducting tests and processing the results", says Sylvain Calloch.

The sea as an application domain

As it took place in Brest, the congress was obviously going to cover the marine world, with subjects examining renewable marine energies, the naval and nautical sectors (including sail propulsion and hydrofoils), ocean hydrodynamics, underwater robotics etc.

"Corrosion leading to early structural aging is one of the specific features of the marine world" explains Sylvain Calloch. "Building a race boat requires the use of high-performance composites, the behavior of which needs to be studied. In shipbuilding, you need to take into account the service life of the vessels (about 40 years) and use all possible means to reduce the maintenance costs and ensure the service life. And all of that is on an case-by-case basis, as the boats are not built in series like a car".

The congress participants, most of whom do not work in the maritime sector, were informed of the theme through plenary and semi-plenary sessions, including, for example,

Naval Group, the Musée National de la Marine, and the GSea Design company from Lorient on the "Design and Sizing of Competition Sailboats".

The theme of renewable marine energies was also covered in depth, especially by France Energies Marines. During a semi-plenary session, Jean-François Filipot, Scientific and Technical Director, presented the breaking wave measurement campaign on the Jument Lighthouse, off Ushant Island. The aim of such a study: evaluate the impact of giant waves on maritime structures such as wind turbines. Jean-François Filipot then led a session dedicated to mechanics for renewable energies. As for Antoine Maison structural calculations engineer (ENSTA Bretagne 2015 graduate), he presented a study on the modeling of seafloor marine turbine electric cable stability in areas of strong currents.

A French congress with an international dimension

There was an international dimension to the congress as demonstrated by the delegates who came from 16 different countries. Moreover, the CFM hosted the associated event EuroMech, organized by the European Mechanics Society, a society which brings together European specialists in mechanics. Presided over by Peter Davies of Ifremer, this symposium was dedicated to the aging of polymers in the marine environment.

The CFM was also the occasion for the IRDL to discuss the European RAMSSES Project. This project brings together 37 partners (including the IRDL/ENSTA Bretagne) over the concept of future ship design. The IRDL is also in charge of the following subjects: propulsion systems/propellers and the assembly of composite superstructures on metal parts.

The Extremely Large Telescope



assembling # bonding # welding
 # sintering # additive manufacturing
 # multi-materials

25 STAFF including
 8 DOCTORAL STUDENTS

7 PUBLICATIONS
 in peer-reviewed
 journals

FOCUS

ADHESIVE BEHAVIOR FOR THE DESIGN OF THE ELT (EXTREMELY LARGE TELESCOPE)

Built in Northern Chili by ESO (the European Southern Observatory) in partnership with Safran Reosc, the ELT is on an exceptional order of magnitude. Thanks to its main, 39m wide mirror and its ideal location (3060m altitude in the Central Andes) it will be able

to gather 15 times more light than the current VLT (Very Large Telescope) enabling stellar archaeology and the search for far away exoplanets. Safran Reosc started work on a thesis in 2016 in order to understand the influence on tempera-

ture on the structural adhesive behavior. After 3 years of work, many macroscopic and microscopic phenomena were revealed and helped the engineers at Safran Reosc in their design and sizing stage.

MULTI-MATERIAL ASSEMBLIES

(PTR2)

KEY RESEARCH THEMES

The aims of the IDRL research cluster "Multi-Material Assemblies" are the innovation of assemblies, the characterization of their long-term durability in extreme environments and the development of hybrid techniques.

- Studying and optimizing assembly procedures by assembling different types of materials, treated with new surface preparations.
- Examining assemblies throughout, using instrumentation (FGB, QRS, CIN...) and original experimental initiatives
- Developing sizing tools for adhesively-bonded assemblies including the parameters associated with bonding procedures.
- Characterizing the performance of assemblies in harsh environments over the long term.
- Developing hybrid techniques (weld bonding etc) for multi-material structures to obtain high performance material characteristics.

RESEARCH PROGRAMS

- Simplified modeling of a SCARF joint test in order to characterize the mechanics of adhesively-bonded assemblies (financed by the Regional Council of Brittany – Région Bretagne.)
- Development of a multi-material structural bonded assembly providing ballistic protection (financed by the DGA, with 2CA).
- Development of technological testing to validate the behavior modeling of impact effects on an adhesive (financed by SAFRAN Composites).
- Durability of structural adhesives used in applications for space optics in thermal environments (with SAFRAN Reosc).
- Analytical and digital modeling of the lateral buckling of offshore pipes (financed by the Regional Council of Brittany – Région Bretagne).

5 THESES BEGUN IN 2019

- **Amen BENALI** (Cifre ECM-BE): "Consideration of the influence of different structural adhesive procedures on the sizing method of adhesively-bonded assemblies".
- **Marthe LOISEAU** (financed by the DGA, Coldpad; with IFSTTAR): "Creep resistance under loading of adhesively-bonded fasteners for subsea applications".
- **Leandro MAURICIO DA SILVA** (Cifre PSA): "Mastering the differential expansion on the scale of a structurally bonded multi-material assembly body-in-white".
- **Cyril BERNOLIN** (financed by Safran Composites and the Regional Council of Brittany – Région Bretagne): "Crack propagation in adhesively-bonded assemblies subject to monotonic and cyclic loading for different mode combinations".
- **Paulo GUIMARES** (financed by the Nouvelle Aquitaine Regional Council – Région Nouvelle Aquitaine, with Nobatek INEF4): "Durability of high thickness bonding using high elongation adhesives. The mechanical and physico-chemical aspects".

CONTACT

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RESEARCH

STRUCTURE, FLUIDS & INTERACTIONS

(PTR3)



KEY RESEARCH THEMES

The research focuses on fluid-structure interactions, the dynamic behavior of materials and structures and detonics. The applications are for naval architectures, marine energies, defense, aerospace, automobiles as well as manufacturing processes.

- Naval hydrodynamics and the study of the response of structures in interaction with fluids.
- Characterization and modeling of the response of metallic and composite materials and structures subjected to dynamic loading.
- Study and modeling of impact phenomena and explosions in complex environments.

RESEARCH PROGRAMS

- The Windkeeper program, to design a maintenance vessel for offshore windfarm turbines has finished. The work concerned the analysis of the hydrodynamic impacts of waves on the bridge.
- COMPADD : characterization of a composite assembly obtained by additive manufacturing under dynamic loading (with Mines ParisTech).
- Projet on supersonic projectile deceleration through liquid foam (financed by the DGA/AID; with the Institut de Physique de Rennes).
- The **SOLID SAIL** project is continuing. This innovative, 100% composite rigid sail of over 1000 m² created by the Chantiers de l'Atlantique, will propel the future largest sail cruise liner (Silenseas). The ENSTA Bretagne team is contributing to the sizing calculations and trials. It is bringing its expertise in fluid-structure interactions and non-linear simulations to model the constraints experienced by the sail panels and predict propulsive global stresses.

7 THESES DEFENDED IN 2019

- **Antoine MORVAN** [ADEME contract; with CNIM]: "Impact on the wet deck of a ship for offshore wind turbine maintenance" (Windkeeper project).
- **Julien ERCOLANELLI** [CIFRE GEPS Techno; with Ifremer] : "Numerical and experimental study of a dual wave energy stabilizer/recuperator system".
- **Gonzalo DOISENBAT** [Regional Council of Brittany – Région Bretagne contract, Ifremer]: "Digital and experimental modeling of offshore wind turbine energy harnessing".
- **Mourad NACHTANE** [Eiffel grant, with the Moroccan University of Hassan II, Casablanca]: "Marine turbine composite material performance studies".
- **Mohamed Chams Eddine EZZINE** [PROFAS B+ contract; with the Algerian University of Djillali Liabès]: "Damage and failure of hybrid assemblies: rivets-adhesives".
- **Youssef BELABED** [with the Algerian University of Aboubakr Belakaïd]: "Study and analysis of the delamination of structures reinforced by multilayer FRP composites".
- **Quentin RAIMBAUD** [DGA grant]: "Modeling and optimization of shock wave absorption by liquid foams, tests on a film scale and film series".

FOCUS

PROLONGING THE SERVICE LIFE OF OFFSHORE WIND TURBINE MOORING LINES

Two projects are in succession: Polyamoor and Monamoor (financed by ANR/France Energies Marines; with many partners). The use of woven nylon cables will bring a flexible

fastening suited to offshore wind turbines, that will last for 20 years. In addition to Ifremer's aging studies, ENSTA Bretagne has designed innovative tests over several months,

to characterize and model the behavior of these nylon lines. The 2nd project will enhance this model and enable the cables to be instrumented.



- # modeling # digital simulation
- # experimental mechanics
- # materials and structures
- # dynamics # shocks
- # impacts # structure-fluid interactions

36 STAFF including
13 DOCTORAL
STUDENTS

9 PUBLICATIONS
in peer-reviewed journals

+ 12 DOCTORAL
STUDENTS belonging
to PTRI Composites



Fatigue tests on welded assemblies.



#fatigue #aging #fatigue
 resistance #modeling #testing

27 STAFF including
 15 DOCTORAL
 STUDENTS

8 PUBLICATIONS
 in peer-reviewed
 journals

BEHAVIOR AND DURABILITY OF HETEROGENEOUS MATERIALS (PTR5)

KEY RESEARCH THEMES

Research focuses on the assessment, measurement, modeling and prediction of the integrity of materials, structures and electromechanical systems.

- Fatigue and self-heating of materials and structures (metals, composites and organic materials)
- Behavior and fatigue of active materials (piezoelectric or memory-shape materials)
- Thermal and marine aging of organic materials.
- Non-linear behavior of heterogeneous materials.

While answering fundamental scientific questions, this applied research is led with European industries in many sectors, in particular the automobile, aeronautical, and energy sectors, and material suppliers.

RESEARCH PROGRAMS

- Load spectrums for the mechanical sizing of an automotive vehicle (financed by the PSA Group)
- The fatigue life of high cycle naval application drive shafts subject to variable and multiaxial loading (financed by Naval Group).
- A simplified approach for complex cyclic loading fatigue life calculation in a confined plastic zone (financed by DGA).
- Fatigue in short fiber (3D woven) thermoplastic composites for aeronautical applications subject to complex pressure loading: behavior law and sizing criteria (financed by SAFRAN).
- Thermomechanical investigation for the fatigue sizing of parts designed in different materials: polyurethane foams and glass fiber thermoplastics, or elastomers.

2 THESES DEFENDED IN 2019

- **Julien LOUGE** (financed by CIFRE Arcelor Mittal): *"The contribution of the measurement of self-heating to the study of steel fatigue: history and pure shearing effects"*.
- **Thomas GLANOVSKI** (financed by CIFRE Trelleborg): *"Comprehension and modeling of elementary fatigue damage mechanisms of natural rubber"*.

FOCUS

VINCENT LE SAUX HAS OBTAINED HIS HDR

ENSTA Bretagne engineer and doctor, Vincent has obtained his **Habilitation à Diriger des Recherches**. (Accreditation to Supervise Research). His work is on the mechanical behavior and durability of polymer materials. For 10 years in the IRDL, he has characterized and modeled polymer materials (elas-

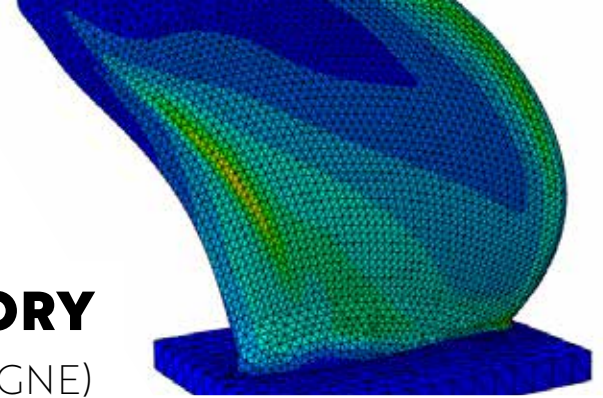
tomers, short fiber thermoplastics, 3D woven composites, polyurethane foams) for the automobile and aeronautics industries. The aim is to obtain a better understanding of the materials and their properties, especially in terms of fatigue, to improve the sizing tools whilst adding certain important ad-

ditional effects (for example, their interaction with the environment or the manufacturing process). These results enable the partners to answer new societal issues, such as minimizing and reducing environmental impacts.

CONTACT

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RESEARCH



GUSTAVE ZÉDÉ JOINT LABORATORY

(NAVAL GROUP, ENSTA BRETAGNE)

KEY RESEARCH THEMES

This joint R&D initiative enables the development of innovative tools to assist in the sizing of naval structures subject to extreme loading.

The teams conduct experimental research and model the issues concerning the resistance and durability of the material used in the military naval industry.

2 KEY SCIENTIFIC THEMES

- The characterization of the fatigue resistance of material and assemblies for naval structures.
- The establishment of digital chains to help size naval structures, taking into consideration manufacturing method effects and effective loading.

MAJOR PROJECTS

- **H2020 RAMSSES European project:** for cleaner and more efficient ships. 37 partners in 11 countries contribute to the 13 fields of innovation which this project covers. The different components complement each other in reducing the environmental footprint of ships. As for the aeronautical and automotive sectors, this reduction is one of the challenges. For this theme, the ENSTA Bretagne team/Naval Group team is in charge of the durability of the adhesively-bonded joints between a composite and a metallic structure. This also includes establishing a high cycle fatigue sizing computational support chain for steel propellers, obtained by additive manufacturing. These models will be validated by full scale testing.

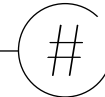
- **EA FRAPAN project (2018 – 2020):** on the characterization and modeling of the fatigue resistance of parts for naval vessels, obtained by additive manufacturing such as WAAM (Wire Arc Additive Manufacturing). It focuses on improving the comprehension of the link between heterogeneity of the microstructuring resulting from such a manufacturing process and the part's fatigue properties. EA INCOLA project (2020–2022). This focuses on the multi-axial fatigue of propeller shafts. The objective of this thesis is the rapid characterization of the fatigue properties of the metallic materials used.
- **A final year project (2020)** will focus on the rapid characterization of the fatigue properties of composite materials.
- **EA AMERICO project** (Improvement of study methods for constructing and industrializing submarine hulls) (2020-2021). Two key themes are examined: shaping and fatigue resistance. The aim is to predict the structure and assembly fatigue (with welded or adhesively-bonded joints) of naval structures taking into account the effects linked to manufacturing processes and the changes in effective loading. The prediction of the mechanical resistance of the naval structures extends to other forms of destruction such as impacts or buckling.

FOCUS

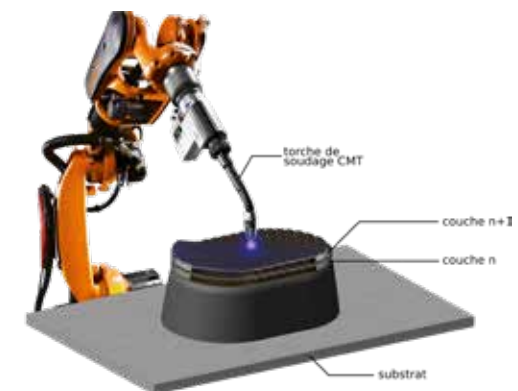
For the last four years, this organization has provided a framework for the programs led by Naval Group and ENSTA Bretagne, and their rapid transfer to the study offices of Naval Group.

The research also interacts through the training of engineers via the implementation of supervised application projects and internships

In November 2019, this joint laboratory was extended in the presence of Hervé Guillou, Chairman and CEO of Naval Group.



added value # transfer
modeling # characterization
fatigue # materials # assemblies
additive manufacturing # steel
composites # naval




Knowledge, Information
and Communication
Science and Technology
Laboratory
UMR 6285

LAB-STICC

JOINT RESEARCH UNIT

PROFILE


- The Lab-STICC laboratory is a multidisciplinary center of excellence, created in 2008.
- Jointly supervised by the CNRS and 5 Breton establishments, it unites research teams in information and communication sciences and technologies in 3 graduate engineering schools and 2 universities: IMT Atlantique, ENSTA Bretagne, ENIB, UBO and UBS.
- CNRS Joint Research Unit 6285, the laboratory is attached to the INS21 as its main institute and the INSIS as its second institute.
- **566** staff, including 206 doctoral students.
- Approximately **450** publications /year.
-  www.labsticc.fr



ENSTA Bretagne is the
3rd most prolific
contributor to the Lab-STICC

Lab-STICC / ENSTA Bretagne key figures


104
PUBLICATIONS


55
SUPERVISED THESES


5,8 M€
NOTIFIED CONTRACTS

THE LAB-STICC SCIENTIFIC PROJECT

From sensors to knowledge : communicate and decide.

Fundamental and applied research unit, with a high level of interactivity with its socio-economic environment, the Lab-STICC is a fount of multiple extremely high level skills concerning digital and communicating systems. Its excellence and high rate of scientific output are the keys to its solid, international reputation.

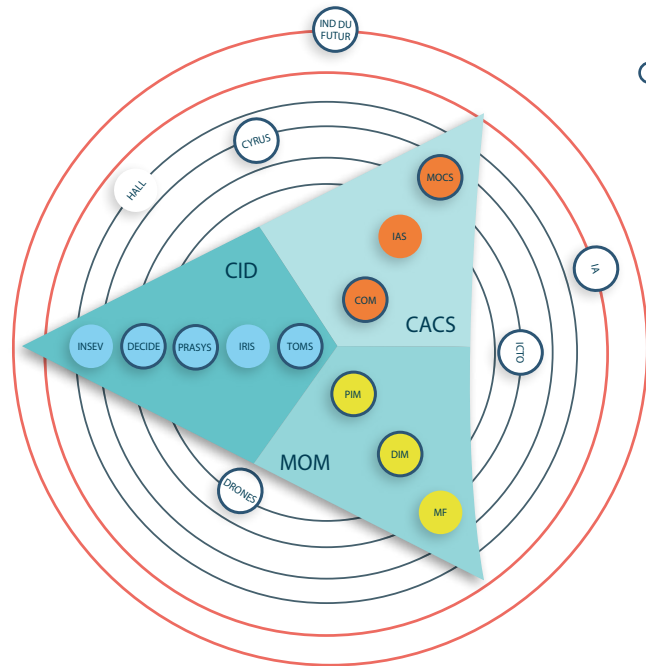
The laboratory is organized in 11 teams, divided into 3 scientific departments, to which ENSTA Bretagne is a contributor:

- MOM : Microwaves, Optoelectronics and Materials.
- CACS : Communication, Architecture, Circuits and Systems.
- CID : Knowledge, Information, Decision.

Further to these disciplinary divisions, transversal programs answer highly interdisciplinary societal challenges such as :

- Assistance devices for the dependent
- Cybersecurity and cyberdefense
- ICST and the sea
- New information representation and processing methods for artificial intelligence.
- Drone systems

○ THE MAIN SCIENTIFIC TEAMS INVOLVING ENSTA BRETAGNE



○ THE ENSTA BRETAGNE TEAMS

Covering **3 scientific poles** of the Lab-STICC. Contributes to **6 of the 11** scientific teams and **5 of the 6 transversal fields**. **Heavily involved** with the socio-economic environment.

IN THE CID POLE (KNOWLEDGE, INFORMATION, DECISION)

TOMS : Processing, Observation and Statistical Methods
[cf. page 42]

PRASYS : Perception, Robotics Autonomous Systems
[cf. page 43]

IN THE CACS POLE (COMMUNICATION, ARCHITECTURE, CIRCUITS AND SYSTEMS)

COM : Digital COMMunication
[cf. page 44]

MOCS : Methods, Tools for design of Architecture and Circuits
[cf. page 45]

IN THE MOM POLE (MICROWAVES, OPTOELECTRONICS AND MATERIALS)

PIM : Multi-scale Propagation and Interaction
[cf. page 46]

INDUSTRIAL CHAIRS AND JOINT LABORATORIES

LATERAL Lab-com with THALES TOSA

on technologies for microwave, antenna and guidance devices for embedded systems.

WAVES Lab-com with THALES DMS

on improving autonomous and distributed sensor network performance for detection and automatic identification in the marine environment.

APRIL 2019 Creation of the TRANSNUM Chair with THALES

The chair includes Thales DMS, ENSTA Bretagne and ISEN Brest. Its aim is to develop new autonomous observation and surveillance systems for the marine environment. The school brings its recognized knowledge in marine robotics and sensor networks.

NOVEMBER 2019 Creation of the SENI Lab-com with NAVAL GROUP

This joint laboratory aims to design intelligent naval embedded systems, that acquire information on the environment and vessel function, and to implement decision and action processes on board.

DECEMBER 2019 ENSTA Bretagne joins the naval systems Cyberdefense chair

With the support of the Marine Nationale [French Navy], the Regional Council of Brittany and the Cyber Center of Excellence, the chair aims to protect digital equipment and detect cyber attacks in maritime systems.

10 theses have been undertaken, supervised by the 5 partners (École Navale, IMT Atlantique, Naval Group, Thales, and ENSTA Bretagne).

PROCESSING, OBSERVATION AND STATISTICAL METHODS

(TOMS TEAM)

KEY RESEARCH THEMES

The Lab-STICC contributes to the methodological and practical aspects of signal and image data processing, in underwater and air environments.

- Development of estimation methods, statistical detection and acoustic and electromagnetic signal representation.
- Monitoring of the underwater environment : localization of acoustic sources, characterization of the environment, the nature and evolution of the depths, detection and recognition of objects, bathymetry, halieutic resource studies.
- Spaceborne and airborne remote sensing: space-time estimation of geophysical fields and ecological dynamics; object detection and recognition [ships, planes etc]; surveillance of zones of interest [pollution etc].

FOCUS

INTERNATIONAL COOPERATION IN BIOACOUSTICS

Passive acoustic devices are deployed to follow whale populations, in particular in the south west Indian Ocean. Kate Stafford (University of Washington, in Seattle) has been following them since 2008. She has just received a PhD student from the team to interpret data.

Another example is with the University of Concepción, in Chile, deploying acoustic transponders in other ocean zones, especially off the coast of Chile. These ties became even closer during the World Marine Mammal Conference [Barcelona, Dec. 2019].

RESEARCH PROGRAMS

> IN SIGNAL PROCESSING

- Financed by the DGA : acoustic data processing to characterize the marine environment ; study of physical quantities relevant for machine learning in underwater acoustics and fluctuating environments; detection and recognition of multiple objects on diverse floors through deep learning (with IRISA, UBO, UMR AMURE, MBDA).
- AID financed deep learning methods : scalable techniques for target detection and recognition using heterogeneous data; physics-guided probabilistic deep learning for underwater acoustics.
- European Regional Development Fund : digital analysis of drone data.

> IN BIOACOUSTICS & ENVIRONMENTAL STUDIES

- Contract with the Biodiversity Agency for the passive acoustic surveillance of cetaceans in the second volume of the Marine Strategy Framework Directive (MSFD) established by the members of the European Union).
- OSMOSE (Open Science Meets Ocean Sounds Explorer) : collaborative underwater acoustics project for ocean observation (with IMT Atlantique, IUEM, Woods Hole Oceanographic Institution).

1 THESIS DEFENDED IN 2019

- **Juan Luis ROSENDRO** [Eiffel grant, jointly supervised by the University of La Plata, Argentina]: "Robust techniques for the automatic control of robotic systems".

Spectrogram : marine mammal acoustic signatures.



- # Marine environment # radar image [SAR/ISAR] # underwater bioacoustics
- # passive acoustics # machine learning
- # deep learning # data science
- # big data # target recognition
- # fusion # decision support

29 STAFF
including 9 DOCTORAL
STUDENTS

26 PUBLICATIONS
in peer-reviewed
journals

APPLICATIONS

Underwater bioacoustics, the study and defense of environments (underwater acoustics and radar).

PERCEPTION, ROBOTICS AND AUTONOMOUS SYSTEMS

(PRASYS TEAM)



Thomas Le Mezo Thesis.

KEY RESEARCH THEMES

The development of algorithms for environment perception autonomous robots is based on the mastery of three components: perception, action and their interaction.

An autonomous perception system must simultaneously analyze the data acquired on its immediate environment and autonomously organize its mission, in terms of piloting and navigation. The interaction between the robot and its environment is accomplished by sensors.

> RESEARCH THEME 1 « AUTONOMOUS ACTION »

By using the results from perception, the system must deduce the actions it requires to be able to accomplish its mission according to certain criteria such as efficiency, safety, speed and even energy consumption.

> RESEARCH THEME 2 « AUTONOMOUS PERCEPTION »

The system endeavors to understand its observations and formulate an accurate representation not only of the state but also the uncertainty of its current environment.

RESEARCH PROGRAMS

- NAVIDRO : development of a precise navigation simulator for autonomous underwater vehicles (financed by the SHOM).
- CHIMAERA : lasers, net detection and avoidance, underwater communication (financed by the DGA ; with OXXIUS, Thales, IMT Atlantique).
- Ident3D : 3D data processing to assist in mine identification (financed by the DGA TN Brest).
- BathySat : satellite bathymetry estimation using multispectral images (for Hytech Imaging).
- Physics-guided probabilistic deep learning for underwater acoustics (financed by DGA AID)

4 THESES DEFENDED IN 2019

- **Thomas LE MEZO** (financed by DGA and the Brittany Regional Council – Région Bretagne) : cf.focus
- **Gaspard MINSTER** (financed by ANR) : « Modeling the salination process [sediment movement] in extreme environments. Application in the Raz Blanchard ».
- **Thibaut NICO** (CIFRE ECA Robotics) : « Study and development of underwater object relocation solutions using heterogeneous underwater vehicles ».
- **Vincent MYERS** (financed by Defence & Research Canada) : « Processing, interpretation and exploitation of SAR antenna sonar images obtained from repetitive trajectories ».

FOCUS

AUTONOMOUS ROBOTS IN SEA CURRENTS

In order to carry out lengthy missions over long distances, Thomas Le Mezo's thesis uses sea currents as the main means of propulsion. A new type of underwater robot has been developed (cf. photo) and validated at sea. New theoretical tools have

also been proposed. This is a major contribution to the validation of the safe use of cyber-physical systems. This work has been endorsed by many scientific publications in international journals (IEEE TAC, AMC, IJC).



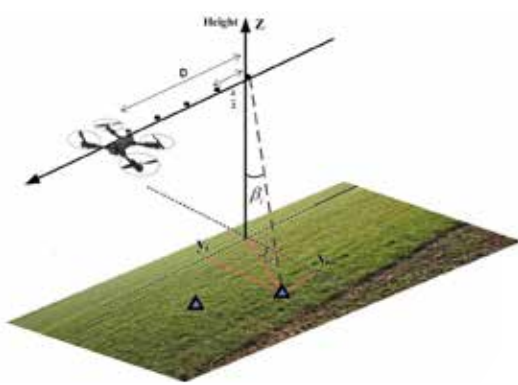
Mobile robotics
autonomous system # localization
perception # control

33 STAFF
including **18 DOCTORAL STUDENTS**

33 ARTICLES
in peer-reviewed journals
and conference
proceedings + **2 books**

APPLICATIONS

Defense and security,
underwater archaeology,
missions in hostile
environments.



- # Blind source separation
- # higher order statistics
- # signal processing # robotics
- # telecommunications
- # electronic warfare # cognitive radio # biomedicine

16 STAFF
 including 8 DOCTORAL
 STUDENTS

2 PUBLICATIONS
 in peer-reviewed journals
 + 2 books and 1 chapter
 in an edited volume

APPLICATIONS

Telecommunications, electronic warfare, robotics, embedded systems, the Internet of Things, biomedicine...

DIGITAL COMMUNICATION

(COM TEAM)

KEY RESEARCH THEMES

The team is interested in statistical methods and signal processing algorithms, focusing on antenna systems and the miniaturization of electronic circuits.

FOCUS

MULTI-LAYER DIGITAL ANALOG SYSTEM FOR CYBERDEFENSE OR RADIO MONITORING

› StCyber Project ; financed by DGA ;
 ensta-bretagne.fr/stcyber/

An attack on our communication systems would doubtless be extremely serious or even critical. Indeed, communication technologies and our communicating and intelligent machines are everywhere in everyday life. Means of communication (base stations, GPS, drones, sa-

tellites) can be subject to noise and radio interference and also the target of enemy attacks. This innovative project will enable efficient protection within a cyberdefense strategy, by improving our ability to ensure radio monitoring.

RESEARCH PROGRAMS

> TELECOMMUNICATIONS

- Estimating communication channel characteristics for better broadcasting and information protection.
- Game theory for the development of protocols for tactical cognitive radio.
- Smart Antenna & Beamforming : the antenna must self-adapt to its environment
- The Internet of Things and wireless network issues related to the coexistence of machine-to-machine (M2M) and human-to-human (H2H) communications.

> MEDICAL APPLICATIONS (WITH THE HÔPITAL DES ARMÉES MILITARY HOSPITAL AND CHRU UNIVERSITY HOSPITAL OF BREST)

- The acquisition and processing of electrocardiograms of the foetus and its mother using wireless sensors.
- Characterization and classification of deep vein thrombosis (blood clots).
- The use of EEG [electroencephalographic] signals and EMG [electromyograms] for wheelchair control by the paraplegic..
- The use of EOG [electro-oculographic] signals for web page activation and surfing by the paralyzed: creation of an ECG sensor and simulator for the Faculty of Medicine.

2 NEW THESES IN 2019

- **Rida MORTADA** (financed by a Lebanese grant) :
 « Energy harvesting in a cognitive radio ».
- **Marwa IBRAHIM** (financed by a Lebanese grant):
 « Ecoenergetic strategies combined with Big Data analysis in wireless sensor networks ».

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RESEARCH



Projet Ker-Seveco.

METHODS, TOOLS, CIRCUITS AND SYSTEMS

(MOCS TEAM)

KEY RESEARCH THEMES

Their key focus is software engineering methodologies. The applications are numerous : intelligent cities, connected houses, e-health, and defense. All of these require connected, embedded systems.

The focus on software is dominant, very heterogeneous due to the diverse equipment which interacts, and must offer secure use, secure communications and data protection. To that, we can add the many expectations of industry in terms of software : more rapid and secure design, easier development, the capacity to virtualize and simulate, the management of variables etc. The main scientific themes: heterogeneous model federation, formal verification techniques, securing compilation flow for reconfigurable circuits, the virtualization of reconfigurable architectures for sustainable and secure system on chip (SoC) design, variability management for product line design.

RESEARCH PROGRAMS

- EASE4SE (completed in 2019) : the federation of executable models for the operational simulation of defense systems.
- VeriMoB (continuing in 2020 with PragmaDev) : execution and formal verification of system to system models described using NAF (NATO Architecture Framework). The PRO-CESS tool has been developed and integrates the formal verification engine OBP2[www.obpcdl.org].
- Securing overlay architectures for the long-term operational maintenance of digital circuits in operational condition (continues in 2020)
- JoinSafeCyber : designing a design and analysis framework enabling critical system modeling and refinement taking into account both the relative reliability and Cyber Security requirements.

1 THESIS DEFENDED IN 2019

- **Vincent LEILDE** (financed by the Brittany Regional Council - Région Bretagne): « Formal system verification diagnostic support ». This thesis was led within the framework of the DEPARTS (Design Patterns for Real-Time and Safe applications) project, financed from 2013 to 2018 by the future investments program on « Briques Génériques du Logiciel Embarqué » [Embedded Software Generic Blocks].

3 NEW THESES IN 2019

- **Emilien FOURNIER** (financed by the Pôle d'Excellence Cyber and the Brittany Regional Council - Région Bretagne): « Threat anticipation during critical system execution ».
- **Grégoire DE BROGLIE** (finance by DGA) : « Furtive communication via software radio with airborne drones in a cognitive radio context ».
- **Maelic LOUART** (financed by the Brittany Regional Council -Région Bretagne; the Cyber-Naval Chair) : « Automatic real time detection of AIS tampering ».

FOCUS

KER-SEVECO

A new project which aims to develop products and services integrated in connected vehicles, as well as the associated external services. These services embedded in the vehicle will have followed a secure development process. ENSTA Bretagne is involved in the development of a design

methodology and a specially-designed cybersecurity test toolkit for "connected vehicles". This methodology must encompass the system, integrating security requirements, through to the communication modules of the embedded computer. The expected outcome of the project will be the development of new

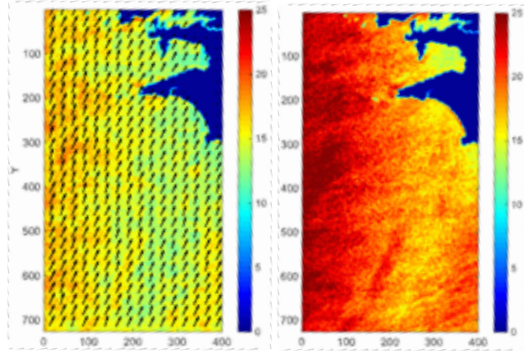
mobility services such as fleet management, the development of a Cyberlab to ensure service security testing and a methodological formal security requirement based package. 3 partners: KEREVAL, Mobility Tech Green and ENSTA Bretagne.



safety # security # embedded systems # system design # circuit virtualization # model federation # formal verification

16 STAFF
including 10 DOCTORAL STUDENTS

22 ARTICLES
in publications
and international
conference proceedings



Wind fields estimated using satellite radar images.



Sensors # radar # GNSS
 # GE # propagation channel
 # clutter # electromagnetic
 modeling # target signature
 # environment # remote sensing
 # inversion # experiment

15 STAFF
including 8 DOCTORAL
STUDENTS

14 PUBLICATIONS
in peer-reviewed journals
and international
conference proceedings

APPLICATIONS

Radar : electronic warfare ;
 geolocalization and navigation ;
 marine pollution ; surveillance ;
 maritime safety and security :
 microwave remote sensing ;
 target detection/reconnaissance
 and tracking [using radar
 images/signals].

MULTI-SCALE INTERACTIONS AND PROPAGATION

(PIM TEAM)

KEY RESEARCH THEMES

This research aims to integrate more artificial intelligence in acquisition and exploitation systems for radar type observations (airborne or satellite) or GPS type geolocalization.

The teams orient its research towards the development and improvement of modeling and optimization tools for the representation and comprehension support of phenomena generated by the interaction of electromagnetic waves with the environment. These phenomena are observed on different scales.

- Modeling and multi-physical, multi-scale electromagnetic simulation
- Propagation and interaction of waves with the environment (sea, atmosphere, land)
- Modeling and simulation of microwave systems [link budget, remote sensing, microwave, experiments...]

FOCUS

DETECTION AND TRACKING OF MARINE TARGETS USING RADAR DATA

These algorithms use thresholdless measurements in scenario where conventional approaches have failed, due to weak signal to noise (SNR) ratios or environmental constraints. An original algorithm was developed in partnership with Diades Marine, in the context of the ADEME e-PANEMA project [e-Positioning et Aide à la Navigation en Environnement Maritime] and was awarded the IEEE Antennas and Propagation Society Award, 2019. It was developed using particle filters for the detection and tracking of targets; its performance was evaluated with the help of real radar data.

RESEARCH PROGRAMS

- e-PANEMA : e-positioning and navigation support in the maritime environment (financed by Ademe ; with SAFRAN, Diades Marine, ENSM).
- CEPAMOCS : Characterization and retrieval of heterogeneous sea surface parameters observed by different satellite sensors (financed by DGA, AID, EGS).
- SLERECIM : The addition of GBS and GBL to the estimation of complex target reflectivity at sea (financed by DGA, AID, OAR).
- RCS measurements of targets in free space (financed by Naval Group)
- DOREDO : Detection of obstacles by radar embedded on drones (financed by DGA ; with CESTIM, CNAM Paris).
- TAPERE : Scalable deep learning techniques for target detection and reconnaissance using heterogeneous data (financed by DGA, AID, I2R).

3 THESES DEFENDED IN 2019

- **Nāïma AMROUCHE** (financed by an allowance from the Algerian Government ; with the National Polytechnic School of Alger) : « Detection, localization and tracking of maneuvering targets – Methods and algorithms for target tracking ».
- **Honglei ZHENG** (Chinese grant ; with the Ocean University of Qingdao, China) : « Study of the electromagnetic signature of a sea surface with and without an oil slick ».
- **Clément ROUSSEL** (DGA grant) : « Stochastic differential equations for the electromagnetic field issuing from the sea surface; remote sensing applications ».

CUTTING EDGE EQUIPMENT IN THE RESEARCH INSTITUTE

FOCUS

A 1,600 m² extension in mechanical sciences

The research institute in mechanical sciences has been extended. A new 1,600 m² building, over two floors, was inaugurated in March 2019, bringing the total surface area for the IRDL Laboratory to 4,000 m². The new testing facilities have also been progressively deployed. A space is dedicated to the study of pyrotechnic phenomena and many other specialized rooms boast sophisticated equipment for studying mechanical properties, such as a triboindenter for observations and measurements on a nanometric scale. This new building also encourages the growth of research teams and the integration of research professors and teachers, doctoral students, post-docs and interns to the Dupuy de Lôme Research Institute (IRDL).

A 850 m² renovation dedicated to cybersecurity

After a total renovation of the information technologies wing of the research institute (the Lab-STICC Laboratory), a research facility dedicated to cybersecurity programs was inaugurated in October 2019. It is comprised of several offices, secure rooms and much equipment acquired within the framework of the "Cyber SSI" strategic project.

Acquisitions on-going within the CPER 2015-2020 framework

The exceptional test facilities in ENSTA Bretagne's research institute have been completed thanks to the strategic programs defined by the Contrat de Plan État-Région (CPER) Regional Development Plan. For the 2015-2020 period, 5 subjects were led by ENSTA Bretagne.

- Cyber SSI (cybersecurity of software and physical systems)
- SMD-MAR (marine environment observation using autonomous underwater robots).
- SOPHIE (maritime environment characterization by a microwave system).
- I-ROMI (design of new, passive acoustic observatories, following submarine ambient noise relating to geological phenomena, fauna and human activities).
- ECO-SYS-MER (to ensure the reliability of mechanical systems interacting with the marine environment, from the scale of the material to that of the system).

**5 strategic research
programs representing
new equipment worth
5,6 M€ from 2015 to 2020
(financed by the CPER¹),
be it 635 k€ of investments
for the year 2019.**



The MASMECA technology platform

It occupies 1,200 m² of ENSTA Bretagne's research institute. Its numerous experimental facilities aim to characterize the mechanical properties of all types of materials, assemblies and structures, on several scales, studied by the IRDL Laboratory. 5 experimental centers:

- Dynamic characterization (high speed load tests)
- Thermo-mechanical characterization (controlled environment and mechanical condition loading)
- Physico-chemical characterization (evaluating the effect of microstructure on the mechanical behavior of materials)
- Measurements and observations
- Prototyping

More info : masmeca.ensta-bretagne.fr
<http://bit.ly/MASMECAfr>



ENSTA Bretagne's information technologies resource center also boasts extensive experimental facilities :

- Anechoic chamber
- Soft Defined Radio Platform
- Drone systems and robotics area
- Test tank
- Hydrographic vehicles
- Cyber area ...

¹ CPER : Contrat de Plan État-Région (the state regional development plan)

Professional training
and apprenticeships
training
EA 7529


FoAP

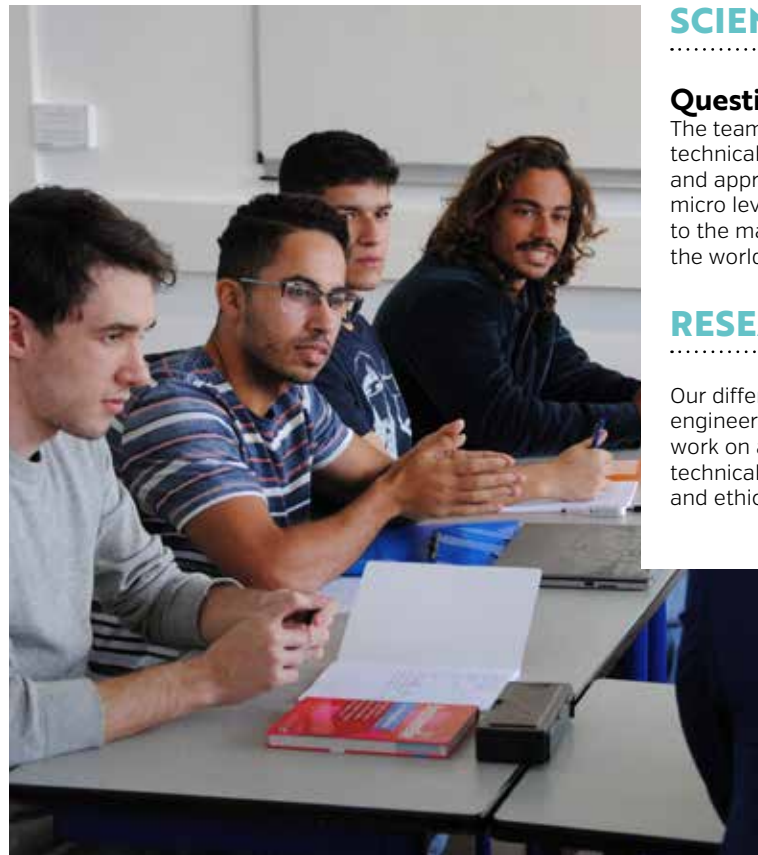
RESEARCH UNIT

99
MEMBERS, INCLUDING
44 DOCTORAL
STUDENTS, AND
27 RESIDENT
FELLOWS,

— ○ —
INCLUDING 22
RESEARCHERS AND
13 DOCTORAL STUDENTS
IN THE ENGINEER
TRAINING AND
PROFESSIONALIZATION
TEAM (FPI)

PROFILE

- Created on 1 January 2019, FoAP replaced the CRF [Centre de Recherche sur la Formation - Training Research Center]
- It unites the human science teams of ENSTA Bretagne, Cnam Paris and AgroSup Dijon.
- Under « Hosting Team » status : EA 7529
- It is under collegial governance. Denis Lemaître, professor at ENSTA Bretagne was named as its director.
-  bit.ly/webFoAP



SCIENTIFIC PROJECT

Question the career and training of engineers.

The team studies the relationship between the social and the technical, from a point of view of identities, knowledge, organization and apprenticeship. They integrate socio-cultural dynamics from the micro level [for example, the individual facing the technical system] to the macro level [for example, engineer training systems around the world].

RESEARCH PROGRAMS

Our different projects focus on the innovation training of responsible engineers in terms of sustainable development in every sense. We work on a sociotechnical approach to problems, which encompass technical, economic, legal, human, social, environmental, political, and ethical components...

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FOCUS

ENGINEER TRAINING AND PROFESSIONALIZATION (FPI TEAM) LAUNCH OF A NEW PROFESSIONAL TRAINING AND APPRENTICESHIP TRAINING LABORATORY (FOAP)

The Cnam Paris, ENSTA Bretagne and AgroSup Dijon have united their human science teams by creating a reference laboratory on Education and Training Science, on a national and international scale, on questions of training in the broad sense : initial professional training, higher education, life-long learning, active apprenticeships, career paths. Engineer training forms a major part, especially the idea of responsible innovation training and sustainable development, an area of particular attention for the FPI team at ENSTA Bretagne. Historically, initial and continuous professional training have been a focus of activity for the Ministry for Armed Forces, and the Ministry for Food and Farming. The two schools, ENSTA Bretagne and AgroSup Dijon, steeped in this culture, have found another establishment for which this is also the main aim – the Cnam. The teams from Dijon, Paris and Brest have thus known each other and worked together for a long time.

Three key themes :

- Designing training, learner knowledge and skill transmission
- Curriculum and identity dynamics
- Activity and professional apprenticeship areas

ENGINEER TRAINING AND PROFESSIONALIZATION (FPI TEAM)

RIIME PHC Maghreb Project

« Recherche sur les Ingénieurs et la formation à l'Innovation au Maghreb face aux enjeux Environnementaux » (RIIME) [Research on Engineers and Innovation Training in the Maghreb facing Environmental Issues] is a project which is financed by the French Foreign Ministry, via CAMPUS France, the Algerian Ministry for Higher Education and Research, the Moroccan Ministry for Research and Higher Education and the Tunisian Ministry for Research and Higher Education. This project, which comprises 7 theses, studies the Maghreb, however, the questions raised may also be pertinent to France and Europe. The objective is to improve the contribution of scientific and technical training, to the training of responsible innovators, aware of major contemporary issues, in a context of complex relations between the needs in the field (companies/states/society), the developments in engineer training, and the extremely strong influence of international reference bodies which want to extend their influence and compete (CTI, ABET, CIDO etc).

Questions on Pedagogy in Higher Education Colloquium, 17 – 21 June 2019 : « (Encouraging) cooperation to (encourage) learning »

This international and French-speaking colloquium was created in Brest in 2001, by IMT Atlantique (Brest site) and ENSTA Bretagne. It rapidly took off and traveled to different towns (Lille, Louvain-la-Neuve, Angers, Sherbrooke, Grenoble) gathering increasing numbers of participants.

For its tenth edition, the colloquium came back home, organized this time by ENSTA Bretagne, IMT Atlantique and the University of Western Brittany (UBO). It brought together 400 teachers and researchers. The diverse activities on offer were a great success : pre-colloquium teacher training, talks, communication presentation sessions, and teaching method workshops.

The A-STEP2030 project

The ERASMUS+ project « Attracting diverse Talent to the Engineering Professions of 2030 » unites higher education institutions promoting innovation for training responsible engineers, able to respond to the societal challenges raised by sustainable development. More than 50 researchers and teachers from 6 European countries came together. The project consortium comprises seven members: ENSTA Bretagne (France), Dublin Institute of Technology (Ireland), Aalborg University (Denmark), Helsinki Metropolia University (Finland), Universum (Sweden), SEFI (European Society for Engineering Education) and BEST (Board of European Students of Technology) from Belgium. The project is coordinated by ENSTA Bretagne, headed by Klara Kövesi.

A-STEP 2030 started in September 2018 for 3 years. It aims to develop an innovative learning approach in agreement with the values and motivation of the learners. The objective is to train them in the necessary skills relating to sustainable development challenges and to attract young people to engineer training who will have this objective. Two European studies have been completed : one qualitative (in 4 European countries) on engineering skills to tackle sustainable development issues,

and a quantitative study (in 6 European countries) questioning the impact of young people's, students' and adult learners' values and motivation on their future choice of career.

The results were shared in three European workshops, four summer symposiums, one national conference, four papers, a webcast and five webinar.

More info: www.astep2030.eu/en

« L codent L créent » project

This project is both a training and research initiative. The percentage of female engineering students is growing (27% of girls on average in 2016 /2017 compared with 19.9% in 1990/1991), but this development is not equally spread over all areas. Research supports the idea that the image and perception of the digital sector is the main explanation for this gap. Programming workshops for the high school girls of 6 establishments in the Brest area (3 in socially deprived areas), led exclusively by female undergraduates and from graduate engineering schools, were set up to try to change this image. From a sociological perspective of actors-actresses, this project aims to investigate the way in which the people involved in this initiative give meaning to their commitment and their actions.

More info: ensta-bretagne.fr/fr/l-codent-l-creent



ENSTA BRETAGNE

**ÉCOLE NATIONALE SUPÉRIEURE
DE TECHNIQUES AVANCÉES BRETAGNE**

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