SCIENTIFIC REVIEW

ENSTA BRETAGNE

RESEARCH

RESEARCH ACTIVITY GEARED TOWARDS DEFENSE AND INDUSTRY

Yann Doutreleau, research director

ENSTA Bretagne conducts its research activities in connection with engineering, addressing the real-world civil and military challenges facing industrial companies and the Ministry for the Armed Forces (DGA, AID). The fields of application are primarily: defense systems, maritime, land and air transport, aerospace, energy and health.

The research teams work within national and international industrial chairs and laboratories, in conjunction with other engineering schools, universities, national research bodies (particularly the French National Center for Scientific Research/CNRS) and the school's longstanding industrial partners.
ENSTA Bretagne's research center is constantly expanding. It has a nearly 300-strong workforce, divided into some fifteen thematic teams. It operates across six buildings (7,500 sq.m.) and boasts significant test facilities in the mechanical sciences, pyrotechnics, IT, cybersecurity and robotics. A 7th building is currently in the pipeline. This will harbor a vast test tank for research on marine and airborne drone systems.

These developments stem from a research strategy focusing on key issues for the future, which has secured financial backing from Europe, the French State, the Brittany region and Brest Métropole. 6 scientific projects involving ENSTA Bretagne teams will receive funding from 2021 to 2027 via the contract for regional development between the French State and the Brittany region (CPER) worth €9.85m in total, on such themes as **naval design, observation of the oceans, drones and space technologies, maritime cybersecurity, industrial digitization, materials for the energy transition and exploratory robotics**.

As demonstrated by the research teams' reports, the contractual momentum and scholarly output (through publications) are once again at an excellent level this year. This is also confirmed by the Times Higher Education (THE) World University Rankings for the "Engineering & Technology" subject in October 2022, in which **the school is in 236thplace globally thanks to the extent of its research links with industry.**

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277
researchers, engineers, post-doctoral students, technicians and PhD students

20
theses defended

247
publications

THIS APPLIED RESEARCH IS CONDUCTED IN 3 MAIN SUBJECT AREAS:

mechanical sciences

IRDL – Institut de Recherche Dupuy de Lôme
UMR CNRS 6285
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P.18

information & communication science & technology

Lab-STICC
EA 7529
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humanities for engineers

Laboratoire Formation Apprentissages Professionnels
UMR CNRS 6027
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FIND OUT MORE

SELF-HEATING ANR INDUSTRIAL CHAIR

Institut de Recherche Dupuy de Lôme in mechanical sciences
UMR CNRS 6027 Institut Carnot ARTS
www.irdl.fr
325 members including 130 PhD students from 4 institutions
(ENSTA Bretagne, ENIB, UBS and UBO)

iRDL
Institut de Recherche Dupuy de Lôme

ENSTA Bretagne has teamed up with Naval Group, three companies belonging to the Safran Group and the Pprime Institute (P') on a sweeping four-year research program. Jointly funded by the French National Research Agency (ANR) and the industrial partners, it is wholly dedicated to measuring the heat signature of various materials in a bid to predict their wear and in-service endurance under cyclic loading.

> **Predict materials' fatigue properties by measuring their heat signature under cyclic loading**

Interview with Sylvain Calloch, holder of the industrial chair, University Professor at ENSTA Bretagne and researcher at the IRDL laboratory

How did the Self-Heating industrial chair come about?

Safran and Naval Group have been long-term partners of our laboratory. They have been supporting and funding our research on the self-heating method to predict the fatigue of materials and structures for many years. This ground-breaking method compared with current conventional approaches makes it possible to swiftly determine the fatigue properties of metals and composites. Through the industrial chair, our research has relevant applications for shipbuilding and aeronautics.
Not only is this method reliable and accurate, but it also has the immense advantage of considerably reducing test campaign times.

What is the chair's program?

To date, and to our knowledge, there is no other equivalent research program at global level.
Safran and Naval Group are committed to extending this scientific approach to all of the materials and assemblies used in their respective applications and to very significantly and swiftly improving knowledge of the parameters acting on the fatigue of their materials (temperature, manufacturing process, type of loading, surface treatments and so on).
The range of manufacturing processes and materials is very broad. It encompasses metals (e.g. high-strength steels, nickel-based superalloys, etc.) and composite materials (e.g. short fiber or multi-layered composites) as well as materials from additive manufacturing.
This will unlock new capacity for innovation for industrial partners in the field of materials and assemblies, to achieve new performances, gain a competitive edge or reduce their environmental impacts. Examples include: improving predictions of the in-service performance of materials and structures, replacing one material with another when resources are tight or prices are too high or using new solutions for manufacturing parts (bonding, additive manufacturing)... thus helping these major industrial sectors to prepare for the future.

You're halfway through the program of the Self-Heating industrial chair. How do you think the last two years have gone?

There have been many constructive findings, both in experimental terms and regarding digital simulation and modeling. These have been presented at a dozen or so international conventions and published in a dozen or so articles in renowned international scientific journals.
Moreover, the industrial partners have received considerable support in adopting the techniques and tools developed, during dedicated day events, training or via the provision of business software.

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THE INDUSTRIAL CHAIR AT A GLANCE

44 researches

Including **12** PhD and post-doctoral students

€2.05 M
Total budget over 4 years co-funded by the French National Research Agency (50%) and the industrial partners (50%)

WHAT EXACTLY IS SELF-HEATING?

The IRDL laboratory has developed a method based on measuring the heat signature of a material under cycle loading, also called measuring the material's "self-heating", to determine the very-high-cycle fatigue properties of structures and materials.

Self-heating under cyclic loading is a change in a material's temperature, observed under precise experimental conditions. It is a sign that the material is starting to wear or sustain damage.
By reproducing, at ENSTA Bretagne's test center, the in-service stress endured by the material or part being studied, this technique enables the prediction of weak points and conditions under which damage emerges, which can then be factored into design office calculation codes, so as to develop parts of a ship, submarine or plane that are exactly the right size.

watch the video

ADHESIVE BONDING OF DIFFERENT MATERIALS

Mechanical modeling, a performance prediction tool for assembling innovative structures by bonding

Bonding is gaining ground across the industrial spectrum for its many advantages in terms of streamlining, combining different types of materials or assembling small structures. These assemblies need to be optimized via modeling to achieve precise performances and lower the carbon footprint of certain activities, comply with new standards or branch out into new markets (new materials, new energy sources, etc.).

With that in mind, manufacturers are calling on researchers at the IRDL laboratory's "multi-material assemblies" research hub, who particularly study the long-term strength of the adhesive and multi-material structure sought, come up with innovations in assembly processes and develop hybrid techniques. "**In the laboratory, we reproduce the industrial assembly process to be studied and perform tests under variable mechanical loading to develop models for predicting how the structure will behave depending on the stress it is being put under,**" explains David Thévenet

One of the research themes concerns assessment of the strength of adhesively-bonded structures under the effect of fatigue, a form of damage which appears in structures subjected to variable loading.
This causes cracks to develop, which then result in the part ceasing to function properly or breaking suddenly. Cyril Bernolin's thesis studied the emergence and spread of fatigue cracks in an adhesive seal to predict the service life of adhesively-bonded aeronautic assemblies in collaboration with Safran Composites.
Another physical phenomenon studied is creep, which is the permanent deformation of adhesive under a sustained load.
In her thesis, Marthe Loiseau studied and modeled the creep behavior of adhesive seals for connectors developed by ColdPad for offshore industrial applications.

2 theses defended in 2022

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LORENZO RECEIVES THE J. POMEY AWARD

The French Society for Metallurgy and Materials (SF2M) has awarded the annual Jacques Pomey prize to a young mechanical engineering researcher, on the theme "Fatigue and Additive Manufacturing". Lorenzo Bercelli stood out for his superb thesis on the fatigue characterization of hollow marine propeller blades, printed by the WAAM process*.

WHAT HAS YOUR RESEARCH CAREER ENTAILED SO FAR?

After graduating in mechanical engineering, I worked as a composites engineer at Naval Group before enrolling at ENSTA Bretagne (IRDL laboratory) to do my thesis there from 2018 to 2021. I was then recruited as a professor in advanced mechanical modeling.

WHAT DOES THE JACQUES POMEY PRIZE MEAN FOR YOU?

It's an honor and a huge source of pride. I presented my thesis during the SF2M's Journées de Printemps event. My research was supervised by the DGA, Naval Group and ENSTA Bretagne's "fatigue" team. It formed part of the sweeping European program "RAMSSES", aimed at enhancing the life span of large naval vessels while reducing their environmental footprint.

WHAT WAS YOUR THESIS SUBJECT?

The impact of the WAAM manufacturing process on a part's durability. The process is similar to large-scale 3D printing, and can be used to design new parts with less metal.

This additive manufacturing technique stacks layers of material, with each layer being a juxtaposition of weld beads. It is a recent production process in industry, where there is a strong need for prediction tools to ensure correctly sized parts.
My thesis provides calculation codes for anticipating the in-service performance, out at sea, of a metal propeller blade produced using the WAAM process, and which is therefore uniquely hollow!

These modeling codes factor in the specifics of this shape, the presence of internal defects in the material layers and the existence of a very rough surface.
My research is continuing under the ANR Self-Heating industrial chair.

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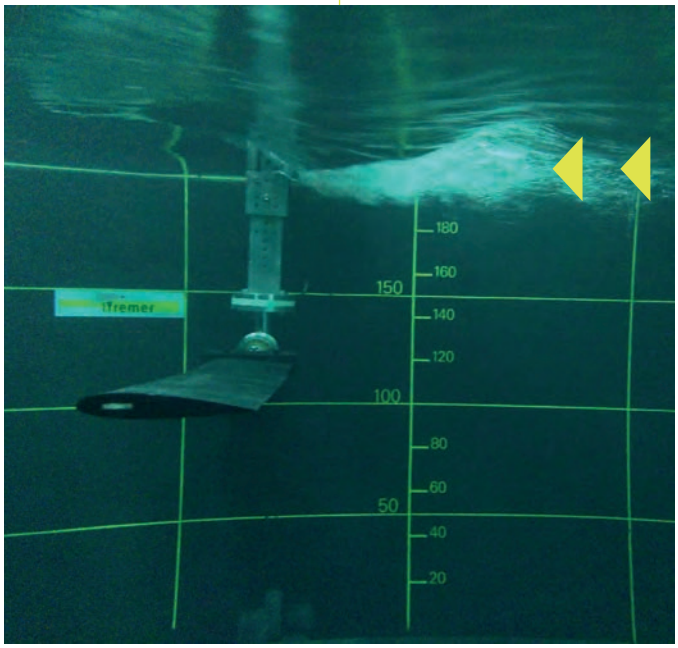
Watch the video about the RAMSSES project

** Wire Arc Additive Manufacturing*

HOW CAN THE PERFORMANCE OF HYDROFOILS BE IMPROVED?

The use of hydrofoils on racing boats, such as IMOCA's boats, allows speeds to be increased. Their use is becoming increasingly popular.



For several decades, underwater wings, known as hydrofoils, have flourished under the hulls of sailboards and sailing boats. Comprising a horizontal part, connected to the hull by a vertical arm, their operation is similar to that of an aircraft's wing. When the boat's speed is high enough, the horizontal part of the hydrofoil lifts the boat's hull out of the water. The friction between the boat and the water is thus reduced and the boat increases speed. This speed is currently sought after for competition sailing boats. However, this is not the airfoil's sole application. Research is under way to reduce the electrical and fuel consumption of future motorboats.

Development of complex models

Improving the performance of hydrofoils is therefore a challenge for the future. This is why a team of researchers in mechanics and hydrodynamics from ENSTA Bretagne (IRDL laboratory [1]), in partnership with IFREMER and IRENav, launched the OptiFoil project in 2020.
«***Ideally, the idea is to develop numerical models capable of assessing the performance of any type of hydrofoil***», said Matthieu Sacher, a lecturer at ENSTA Bretagne and a specialist in fluid/structure interactions.

The modeling of certain physical phenomena, such as ventilation or cavitation which can occur when the hydrofoil operates close to the air/water interface, or the non-linear response of the hydrofoil's structure under hydrodynamic loading, is a real scientific challenge. These phenomena can affect the hydrofoil's efficiency. The challenge is to limit their effects!

Confirmation of the models in tank tests

For this purpose, the OptiFoil project's scientists decided to first test the hydrofoil's performance based on the mechanical properties of its structure. In a water circulation tank at IFREMER in Boulogne-sur-Mer, they studied the hydrofoil's structural response when subjected to a flow. The design of the fibers that make up its structure can indeed affect its performance. «***As the hydrofoil moves through the water, the hydrodynamic forces displace and deform its structure. Bending/twisting couplings can occur and change the machine's speed***». The vertical component of this hydrodynamic force is the lift, which raises the hydrofoil and therefore the boat, and the horizontal component is the drag. «***The experimental results are being analyzed. They will allow us to refine our models». In a second phase, the hydrofoil's geometry will be tested.***»

With the OptiFoil project, scientists will be able to propose models for assessing hydrofoil performance. «***For now, we have focused on stationary case studies. We hope to continue these developments in a future project, including dynamic cases : swell, transitional phases (tacking, trim changes, etc.) or dynamic responses to external disturbances***.»

To carry out this research, the OptiFoil project researchers have set up a dedicated team that includes PhD students and post-doctoral research engineers, as well as ENSTA Bretagne engineering students and Ecole-Navale Master Of Science in research students. The OptiFoil project is funded by the Carnot ARTS and MERS institutes.

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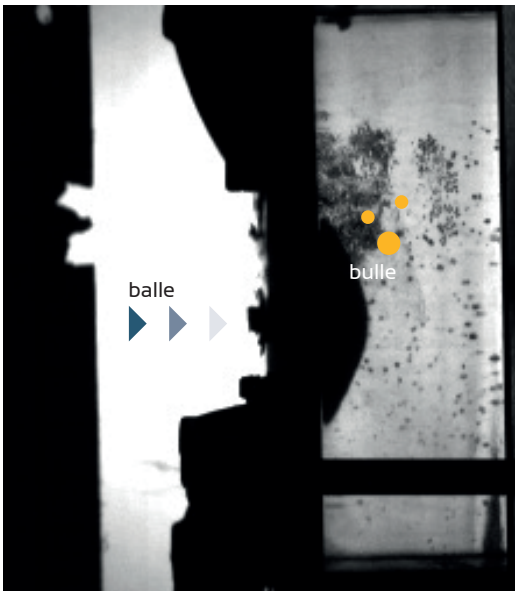
> **Ideally, the idea is to develop numerical models capable of assessing the performance of any type of hydrofoil**

[1] IRDL : Dupuy de Lôme Research Institute - [2] Located in Pas-de-Calais. - [3] Generally made of composite materials. - [4] Which opposes the boat's forward speed

STUDYING THE PYROTECHNICAL PROPERTIES OF MATERIALS AND PROVIDING PROTECTION AGAINST THEM



Implosion of a shock-induced cavitation bubble in a structure containing a liquid, subjected to a ballistic impact of a 9mmx19mm bullet. ANR PROBALCAV project.

ENSTA Bretagne's "Pyrotechnical Systems" team, a member of the IRDL mechanical engineering laboratory, is continuing to study the characterization of the effects of explosions and their barriers.
At the beginning of 2022, Jérémie Tartière defended his CIFRE Airbus thesis on the explosive forming of large metal parts for aircraft.
Three other theses began in 2022. Aymerick Reinders' thesis, financed by the Defense Innovation Agency's COBADI project, sets out to design water-blown foam barriers to reduce blast effects. Baptiste Reynier's thesis, financed by the CESTA center of the Military Applications Division (DAM) of the French Alternative Energies and Atomic Energy Commission (CEA), is studying ejecta emitted during impacts at over 18,000 km/h. Lastly, Julie Morand's thesis, financed by the Le Ripault Center of the CEA DAM, is researching a system for initiating explosives by impact: the latter is generated at high speed thanks to the propulsion of a projectile by the energy of a powerful pulsed laser, the most suitable device for controlling the initiation times of low-sensitivity explosives.

In addition, ENSTA Bretagne has joined the Aeroballistic Range Association, which studies ballistics, guns and launchers, and brings together leading national and international research centers working in this field, including the CEA.

On a final note, a new pyrotechnical testing ground opened in 2022, dedicated to studying very small samples of energetic materials. These are tested with a view to determining their thermomechanical properties. To give an example: using Split-Hopkinson-Pressure-Bars, it is possible to study the impact of a shock on an energetic material propelled at very high speed and to analyze the mechanical damage sustained by the material and the effects on its ignition and combustion properties.

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ENVISAGING FUTURE ELECTRICITY GENERATION AND DEVELOPMENT OF FLOATING WIND POWER

Under the Energy Transition for Green Growth Act, dated August 17, 2015, the French Government expects 40% of France's electricity production to come from renewable sources by 2030. This is an ambitious goal, on which ENSTA Bretagne's maritime engineering and mechanical engineering researchers are working, at the IRDL laboratory.
Together with France Energies Marines and other partners, such as Ifremer and EDF, they have turned their attentions to the offshore durability of floating turbines. These research projects come under the France 2030 investment plan. The advantage of offshore wind power is that it produces 60% more energy than onshore wind power. This is because wind speed is faster and its duration more constant offshore than on the coast. On the other hand, the sea and the strong gusts put offshore wind farms under significant mechanical and physical pressure.
The researchers are developing design and calculation tools to provide robust, hard-wearing systems. The research in progress is particularly seeking to better predict the pressure from breakers and the mechanical properties of new materials – two means of optimizing the in-service performance of wind farms and of lowering costs associated with maintenance operations.
Calculation codes, which can be used for modeling and measuring, are being developed to come up with devices for the future. Future floating turbines will need a mast that is resistant to the most violent waves and storms as well as semi-rigid cables sturdy enough to remain functional for at least 20 years in the sea. These cables either support the platform or route electricity to the continent. There are 6 MW offshore wind turbines today that are capable of delivering electricity to a town of 5,000 inhabitants. But the goal eventually is to produce 8 to 10 MW systems

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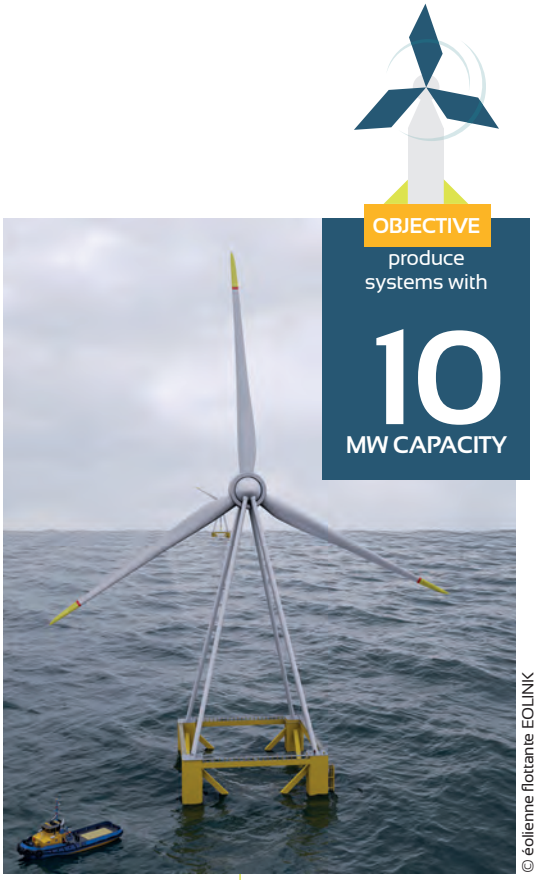

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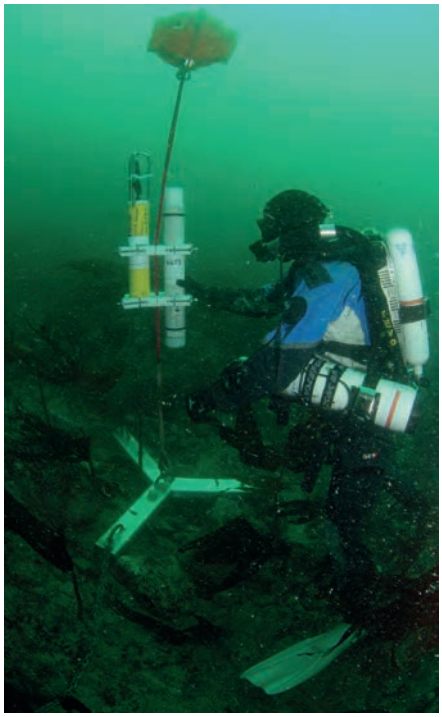
Laboratoire des sciences et techniques de l'information, de la communication et de la connaissance UMR CNRS 6285
www.lab-sticc.fr
640 members including 240 PhD from 5 institutions (ENSTA Bretagne, IMT Atlantique, ENIB, UBS et UBO).
Lab-STICC

PASSIVE ACOUSTICS, A METHOD FOR MEASURING THE SEA'S ECOLOGICAL STATE

The healthy functioning of marine ecosystems depends, inter alia, on the type of species present, their abundance and their diversity. To collect this data, the Observation, Signal and Environment research teams (at the Lab-STICC laboratory) are using a non-invasive observational method: passive acoustic monitoring.



The observatory's 7 listening points (hydrophones and recordings) are retrieved and replaced every 3 months.

Cetiroise, an underwater observatory

The team led by professor Flore Samaran uses underwater recorders equipped with hydrophones to capture the underwater soundscape. The sound recordings are then processed to recognize the different sources of noise and identify which species or groups of species roam in the area in question. In early 2022, at the request of the French Biodiversity Agency (OFB), her team set up the "Cetiroise" project, funded by the European Union's "NextGenerationEU" recovery plan. Seven listening and recording points have been deployed for a one-year period. "***Passive acoustic monitoring is an ideal non-invasive solution for identifying, over a certain time interval and area, the different cetacean species that pass through this maritime region***," explains Flore Samaran.

OSmOSE, a collaborative data analysis tool

To analyze underwater recordings, researchers are also harnessing the open-source data processing tools developed by the research group OSmOSE (which stands for Open Science meets the Ocean Sound Explorers; this is a project supported by the OFB). Launched by ENSTA Bretagne in 2018, its aim is to standardize and share the methods and findings of their research community to make it easier for research teams in the field of underwater acoustics to work together.

To date, the project has enabled development of a data storage and processing platform as well as a web app used for audio annotation. Dorian Cazau, a professor and the group coordinator, explains that "[t]he annotation stage is key for training automated algorithms to subsequently detect the sounds". Both tools are hosted at France's ocean science research institute, Ifremer.

To annotate a sound, and therefore characterize it in the algorithm, it must first be recognized. For that, it must be isolated from the other sounds and visually represented on a spectrogram (2D graph of the intensity of a sound at variable frequencies over time). Citizen scientists, i.e. amateurs, help to analyze the spectrograms. "***By studying the deviations between the amateurs' findings and the experts' conclusions, we can understand in what way our annotation tasks are difficult to carry out, and adapt the development of our tools accordingly***."

Indeed, the group would ultimately like to provide user-friendly tools for training staff working at Iroise Marine Natural Park and the OFB for example.

OSmOSE will thus bring research developments more closely into line with ecology practitioners' requirements.

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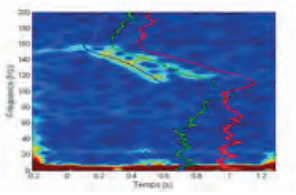

Spectrogramme

The Cetiroise observatory is operated with financial backing from France Relance, the OFB and ENSTA Bretagne, under the recovery plan.

[1] *Open Science meets the Ocean Sound Explorers. Project supported by the OFB.*
[2] *2D graph of a sound's intensity at a range of frequencies over time.*

ROBUSTLY TETHERED UNDERWATER ROBOTS

Christophe Viel has achieved his childhood dream: of becoming a researcher in marine robotics. Since 2021, he has been on a CNRS posting to ENSTA Bretagne, in the Lab-STICC* laboratory's ROBEX (robotics for exploration) team.

This flourishing research field is both theoretically demanding and exciting in terms of its scope for application. A wide range of lake- or sea-based test campaigns are conducted. *"The upcoming construction of the new robotics pool, which should be ready for use in 2024, will significantly ramp up these capacities,"* Christophe points out.

He has been a Doctor since 2014 after defending his thesis on fleets of robots. His current research focuses on tethered underwater drone systems. These ROVs* are commonly used for inspection or maintenance purposes. They are tethered to the surface (platform, dock or vessel) to transmit the video to an operator: *"the drone is the operator's hands and eyes, if you like."*

But the tether's uncontrolled movements can hamper missions as it tends to end up all tangled up. The solution? Pulleys and weights to ballast the tether. The tether angles measured from the surface and the ROV provide information about the location of the robot.

An article was published in Ocean Engineer at the end of 2022 and another is about to be published.

Christophe is also interested in fleets of robots which would significantly increase intervention or inspection capabilities. These situations are even more fraught with challenges.

> **"The upcoming construction of the new robotics pool, which should be ready for use in 2024, will significantly ramp up these capacities**

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TWO ENVIRONMENTAL OBSERVATION AND KNOWLEDGE RESEARCHERS ARE AWARDED THE "HDR"

THE HIGHEST UNIVERSITY RESEARCH QUALIFICATION IN FRANCE

Their subjects may appear to be very abstract and generic. And yet the technological and actionable interests of their research address very tangible applications and significant needs for observation and knowledge of the environment – not least the marine environment.

Angélique Drémeau et Arnaud Coatanhay se sont distingués en présentant leurs parcours et productions scientifiques à l'habilitation à diriger des recherches, le titre universitaire le plus élevé en France.
This HDR, for which they have been congratulated by their peers and colleagues, recognizes their original scientific careers of immense interest for industry and society alike. Angélique's bears on signal processing methods, with a highly developed marine acoustics thrust (sonars), and Arnaud's concerns modeling of the physical phenomena of electromagnetic signal propagation (radars).
Since they joined the teams at ENSTA Bretagne, Angélique Drémeau and Arnaud Coatanhay have geared their research towards environmental observation. Their subjects and the observation systems to which they apply are very different yet highly complementary, not least for the description of the marine and underwater environment.
Arnaud's research seeks to improve radar remote sensing techniques. His contributions to modeling electromagnetic wave scattering and interaction affecting the sea surface have demonstrated their merits in this respect.

Arnaud Coatanhay
Laboratory Lab-STICC, SyPH team

"For me, the HDR is a milestone, an opportunity to take stock and to think about new avenues for research. I have spent the last few years closely studying the contribution that quantum information can make in electromagnetic remote sensing. Incidentally, one of my PhD students has just defended their thesis on this subject, but there is still a great deal left to do!" Arnaud Coatanhay enthuses.
Angélique's research, meanwhile, on variational approximation (variational Bayes), has demonstrated its relevance for underwater acoustics.

"The Bayesian framework (mathematical method) is perfect for modeling the random fluctuations of the ocean environment and then integrating these into multiple-source localization procedures for example. I'm fortunate to work with colleagues who have different areas of expertise (oceanographers, acousticians) and are familiar with the marine environment – they can help me to fine-tune the models. I find the complementary viewpoints so edifying and rewarding," the researcher explains.
This accolade highlights the excellence of the scientific accomplishments thus far and their steadfast dedication to learning and imparting knowledge.

Angélique Drémeau
Laboratory Lab-STICC, DMID team

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SYDACICO PROJECT: OPTIMIZING AIR-TO-AIR AND AIR-TO-GROUND AERIAL COMMUNICATIONS.

This study is aimed at modeling, simulating and optimizing aerial drones' physical communication channels (from the transmitter to the receiver), with account taken of operational contexts.

It is the second stage in a vast research program commissioned by the DGA, the aim being to optimize the quality of communications between an aerial drone and its operator based on land, or between several drones and their operator. Tools for calculating missions and controlling the drones will have to take the operational contexts into account for that, not least such natural features as terrain or dense vegetation, which limit wave propagation.

This path loss coefficient was modeled during the first study. The new study has several additional objectives.
First of all, finding the best routes for maintaining the highest possible path coefficient.
The researchers are developing effective optimization techniques in that respect, which incorporate radar wave propagation models (mathematical theories of optimization).

Other parameters taken into account include flight management and drone orientation. These also affect radio frequency communications and are factored into models using AI algorithms (reinforcement learning).
Finally, mission calculation methods may bring two or more drones into play to ensure this optimization of communications. In that case, the researchers study the extent to which the algorithms developed are capable of coping with the combinatorial explosion inherent in the multi-drone context.

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ONEWAY PROJECT: MODELING CAPACITIES AND DIGITAL ANALYSIS OF A PRODUCT DEVELOPMENT PLAN

As part of the "Oneway" project, conducted in 2021-2022 with 13 other partners, this extensive expertise has been harnessed to improve aeronautical product design & development cycles. It has set the stage for the radical transformation of engineering methods.

The ENSTA Bretagne team was tasked with defining a digital capacity for supporting decisions regarding launch, then control and management of a Product Development Plan (PDP). The PDP seeks not only to predict and control the best date for a product and its industrial system to be brought to the market, but also to determine the timing of the production ramp-up stage.
Such modeling methods and tools have become crucial to ensure the competitiveness of businesses.

Thanks to the experience of ENSTA Bretagne's Processes for Safe and Secure Software and Systems (P4S) team on federating complex software systems, the development of formal semantics and analytical algorithms, an equipped PDP modeling framework has been established.

The tool developed allows for a detailed capture of the business specifics, industrial-scale simulation of the development process and validation of the models built through formal verification methods.

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ENSURING THE CYBERSECURITY OF A MARINE DRONE SWARM

Activities like mining exploration, port or coastal surveillance are increasingly carried out by swarms of drones controlled semi-automatically. The complexity of their networks makes them vulnerable to cyberattacks, however.

To secure the data contained and transmitted between drones, the ENSTA Bretagne/Lab-STICC Software/Hardware And unKnown EnviRonment Interactions (SHAKER) team launched the DISPEED project with the AID in September 2022. Its goal? "**To develop an intrusion detection system (IDS)** factoring in the resources which each of the drones in the swarm needs in terms of energy and calculating capacity," explains Camélia Slimani, a post-doctoral student at ENSTA Bretagne and a member of this team.

The most widespread IDSs leverage machine learning algorithms which require significant memory and computing power. Not all types of drones have the same processing capacities though (processors, memory, storage), which affects their cybersecurity performance. "The challenge is to come up with an execution model which strikes a relevant trade-off between swift detection and energy use depending on the criticality of the attack and state of the system and the mission," the researcher clarified.

The research team initially conducted an energy use and performance study of several existing IDSs before drawing up an appropriate execution strategy for the missions chosen for a population of drones operating autonomously.

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TRUSTGW, AN INNOVATIVE NATIONAL PROJECT TO SECURE INDUSTRY 4.0

The world is growing increasingly connected today, and industry is no exception.
Factories are becoming equipped with ever more connected objects (sensors, actuators, etc.) which provide real-time monitoring of the proper operation of production machinery. The data that these objects collect is then sent to a hardware device known as a gateway, which can analyze this data and detect any anomalies. The whole of this system makes it possible to carry out predictive maintenance. Communication between this gateway and the objects is vulnerable, however. For the data is transferred between remote-controlled objects and the gateway via wireless networks (Wi-Fi, Bluetooth), which can be subject to cyberattacks.

Innovative technologies

The national TrustGW project was launched in 2021 to ensure the secure operation of a factory. It brings ENSTA Bretagne together alongside Université Bretagne Sud, Irisa Rennes and IETR Rennes. Its goal? Implement a cybersecurity solution to protect data when it is being collected by the connected object, transferred to the gateway and analyzed. ***"The project is original in that it entails development of a reconfigurable gateway capable of swiftly processing very large datasets from several sensors using different wireless networks (Wi-Fi, Bluetooth, etc.)***," explains Pascal Cotret, lecturer at Lab-STICC, in charge of developing a prototype for industry. With that in mind, the researchers are particularly using FPGA electronic components for the rapid execution of cryptographic and hashing algorithms for securing data on RISC-V open-source processors. They are also less vulnerable to cyberattacks as they can be reprogrammed over time.
"To make gateway datasets more secure, we partition them depending on their characteristics, separating out the data depending on whether it comes from Wi-Fi- or Bluetooth-connected objects."

A number of industrial players are already showing an interest in the technology developed through the TrustGW project, for the purposes of upgrading existing industrial facilities or installing new protected networks within their future factories.

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> **"The world is growing increasingly connected today, and industry is no exception.**

[1] *Project "Détection d'Intrusion et compromis Sécurité / Performance / Energie, Etude pour les meutes de Drones" ("Intrusion Detection and Security / Performance / Energy tradeoff, a Study for Drone swarms") financed by the Ministry for the Armed Forces Defense Innovation Agency (AID).*

Unité de recherche formation et Apprentissages Professionnels
EA 7529 - foap.cnam.fr
106 members including 40 PhD from 3 institutions (ENSTA Bretagne, CNAM Paris, AgroSup Dijon).

Laboratoire Formation Apprentissages Professionnels

FOAP SCIENTIFIC PROJECT

Multi-supervisory and inter-regional, FoAP (Training and Professional Learning) is the only laboratory to be dedicated to adult training and vocational training in France. It oversees a network of researchers (ENSTA Bretagne, AgroSup Dijon, CNAM Paris) on training questions in the broad sense, including initial vocational training, higher education, lifelong learning, active apprenticeships and career paths.

THE LABORATORY'S SCIENTIFIC PROJECT IS BASED ON THREE MAIN THEMES:

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

RESPONSIBLE INNOVATION TRAINING AND SUSTAINABLE DEVELOPMENT

At ENSTA Bretagne, the "Engineer Training and Professionalization" (FPI) Research Team focuses more particularly on engineers, especially from the point of view of responsible innovation training and sustainable development.

1 thesis commenced in 2022

INNOVATION IN THE ARMED FORCES

The TRAVID project on defense innovation in action, was coordinated by Jean Frances, a sociology professor at ENSTA Bretagne's FoAP lab. The investigations and analyses were carried out with Violette Larrieu, a post-doctoral student in the team, and Damien Coadour, also a professor at ENSTA Bretagne.

Violette : *"We decided to study how the military get involved in innovation. These innovations developed "by and for" the military are grounded in their own experiences. They often concern their matériel and armaments to improve their working conditions and efficiency on duty.*
We focused our research on the Special Forces by traveling to several Units across France and outlining the trajectory of these innovations, from the idea to its scaling up, via the prototyping and certification stages. The report drafted on behalf of the AID presents this innovation work by and for operatives and sets out various recommendations likely to improve the conditions in this regard".

ARE THERE PLANS FOR ANOTHER PROJECT ON THE SAME THEME?

Jean : *«Yes, another one is poised to start in early 2023, called I2DI (innovation in defense, defending innovation). While the TRAVID project mostly related to the sociology field, this one bears more on the political sciences. Our goal is to understand how innovation has become a public policy focus and how it is considered. This involves analyzing the systems implemented by the Ministry for the Armed Forces to encourage innovation. Ultimately, the idea is to combine the top-down and the bottom-up approaches.»*

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In the context of this research, Violette Larrieu has won support from the Foundation for Social Sciences (in the 2023-2024 cohort).

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THE GRADUATES

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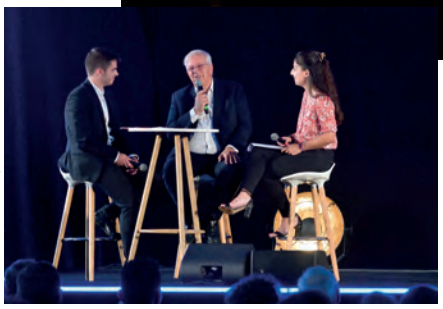

Chairman of VALEO, Jacques Aschenbroich, sponsor of the 2023 cohort

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