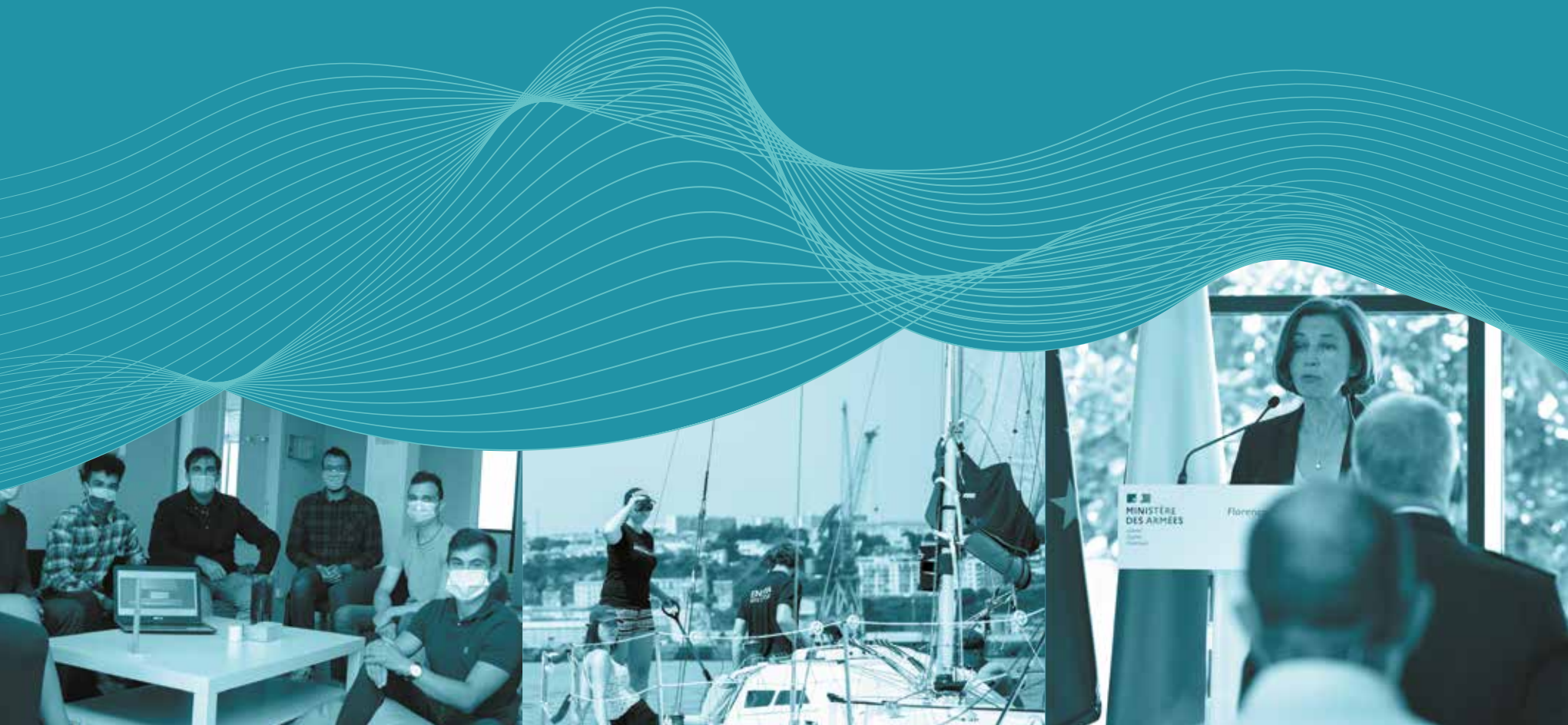




**ENSTA
BRETAGNE**

ANNUAL REPORT 2020



SUMMARY

p. **3** • Edito

p. **4** **COVID-19
TREMENDOUS EFFORTS**

p. **6** **MEMORABLE MOMENTS AND AWARDS**

p. **8** **MISSIONS & AMBITIONS**

.....

p. **9** • An original, pioneering school for the defense, maritime and innovative industries

p. **10** • Our missions

p. **12** • Our fields of excellence

p. **17** • Global standing

p. **18** • A school geared towards hi-tech companies

p. **19** • Our partners and networks

p. **20** **TRAINING**

.....

p. **21** • Edito

p. **22** • Training engineers and experts

p. **24** • Training program projects

p. **26** • Enstartups, ENSTA Bretagne's incubator

p. **28** **RESEARCH**

.....

p. **29** • Edito

p. **30** • IRDL joint research unit (IRDL, UMR CNRS 6027)

p. **36** • Knowledge, Information and Communication Science and Technology Laboratory (UMR CNRS 6285)

p. **44** • Professional training and apprenticeships (FoAP, EA 7529)

p. **46** **CAMPUS**

.....

p. **47** • Sustainable development & social responsibility



Antoine Bouvier, Head of Strategy, Mergers & Acquisitions and Public Affairs at Airbus, "godparent" of the 2021 cohort (October 2020).



Presentation of robotics research projects to Florence Parly, Minister for the Armed Forces (May 2020).



Tour of the campus by engineering freshers (September 2020).

EDITO

2020: an altogether unprecedented year.

Societies big and small have been grappling with the challenges of the global pandemic, and higher education – in France and world-wide – has had its fair share to tackle.

ENSTA Bretagne's teams have demonstrated quite remarkable dedication, responsiveness and creativity. They have reinvented teaching methods, kept in touch with all of our students, whether in France or abroad, and organized the continuity of research activities, all whilst making innovative efforts to support care and rescue teams.

The network formed by the Alumni Association, our industrial partners and research teams has played a key role. This invaluable partnership of engineers, researchers and businesses is crucial for supporting internship-, apprenticeship- and job-hunting against a worrying economic backdrop. I commend the depth of your commitment.

I thank the students who welcomed freshers to Brest and helped their international fellow students to settle in. Thanks to their vigilance, the health protocol we set up has been observed. During lockdown, contact was steadfastly maintained with all of our students, in a tremendous show of solidarity and support.

A school moving forward and planning for the future.

There is still deep uncertainty and widespread concern. We have learned and we are adapting.

The dedication of teams and students alike at ENSTA Bretagne has been highlighted time and again, not least by the external assessors who came to perform the ISO 9001, HCERES and CTI audits in 2020. The auditors also underlined the all-round commitment on a daily basis to the school's benefit.

ENSTA Bretagne's teams have demonstrated quite remarkable dedication, responsiveness and creativity.

France's Minister for the Armed Services, Florence Parly, witnessed this for herself last May during her tour of the

school: "You have a wealth of talent in your laboratories," she pointed out, during her announcement of the stronger ties between the school and the Defense Innovation Agency (AID). She has particularly tasked ENSTA Bretagne with drawing up a road map on maritime innovation [vessels of the future, AI, etc.] with its Brest-based partners.

ENSTA Bretagne has become a partner school of the École Polytechnique. This recognition of our areas of expertise and their appeal to students attending L'X particularly bears on autonomous robotics, hydrography, pyrotechnics, naval architecture as well as all of the school's teaching.

Brittany's first National Research Agency (ANR) industrial chair attests to the expertise of the mechanical engineering team. Dubbed "self-heating", it teams us up with Safran and Naval Group to enhance the prediction of naval or aeronautical systems' in-service performance.

The long-standing volume of research contracts, these defended and publications also highlights just how instrumental ENSTA Bretagne is in the national and international higher education and research ecosystem.

2021 will mark a watershed as a truly defining year. ENSTA Bretagne will be celebrating its 50th anniversary and 30 years of research, proud of its history and of what it has become and looking to the future with confidence. This year we will be charting our road map for the next five years, more than ever cementing our lead as one of France's top engineering schools.



Jean-Georges Malcor
President of ENSTA Bretagne
Board of Directors

Bruno Gruselle
Director

COVID-19

TREMENDOUS EFFORTS



"2020 has been a grueling year. I commend the tremendous efforts on everyone's part, throughout, to reinvent ways of teaching and working. ENSTA Bretagne's teams have continued to adapt quickly, to safeguard the continuity of the school's activities. We have shown our students and our young graduates, with the Alumni Association, that they can count on their school. Help was also immediately forthcoming to lend invaluable material support to the care and rescue teams right from the start of the pandemic.

Thank you to everyone for their participation."

Bruno Gruselle

CONTINUOUS ADAPTATION

March 17, 2020

1st lockdown: all of ENSTA Bretagne's activities continued remotely.

In just a few hours, classes went online.

And video-conferencing gained momentum.

May 11, 2020

As lockdown was eased, classes continued remotely in higher education.

End June/early July 2020

Classes on-campus limited to 1st year co-operative (apprentice) engineers.

August 18, 2020

Campus reopened after the summer recess, under a health protocol laying down the conditions in which classes, research and student activities could resume. Reminders of the protective safety measures and distancing rules were given constantly.

Blended learning, combining classroom and online sessions, was organized, enabling international students stuck in their home countries and other students having to isolate to attend classes.

October 30 / December 18, 2020

2nd lockdown: all teaching once again switched to digital methods.

Support, research and innovation activities were able to continue on-campus. Remote working was encouraged.

In December, only certain types of practicals and exams were allowed to be held in person. Timetables were reorganized so that students in some cohorts did not have to return to Brest after the October half-term break.



€250k invested
in blended learning

INNOVATION & SOLIDARITY

NEARLY 5,000 FACE SHIELDS MADE AND DISTRIBUTED

To meet the needs of the health service, care homes for dependent elderly people (Ehpad), emergency & rescue teams and law enforcement in the Brest region, a team at ENSTA Bretagne seized the initiative, bringing together, in just a few hours, a network of "makers". The call launched over social media was taken up by some one hundred volunteers, individuals and businesses alike, equipped with 3D printers. Plans were tailored and approved by the Brest Regional University Hospital before being shared online. The school's efforts continued at a steady pace, coordinating the implementation, assembly and delivery of 5,000 face shields.

[March-April 2020]



ISOLATION CHAMBER FOR AMBULANCES



30,000 PROTECTIVE GOWNS

One group of students embarked on the production of protective gowns for staff at Brest Regional University Hospital: using scissors to cut out the gowns and belts from plastic sheeting, folding and packaging. In the space of a few days, 30,000 gowns were made and delivered.

[April-May 2020]



Having heard about ENSTA Bretagne's efforts making the protective face shields, "the Ambulanciers de la Rade" got in touch with the school. They wanted an isolation chamber that could be fitted to a stretcher, acting like a sort of "protective bubble" so as to isolate the patient and avoid any risk of contamination. Taking their cue from university studies, two professors designed this chamber by tailoring it to the ambulance drivers' specific working conditions.

[April-May 2020]

NEXT-GENERATION VENTILATORS

How can you regulate, in real-time, the flow, volume and level of oxygen supplied to a patient exactly in line with their needs?

Expertise in robotics and AI has been harnessed to answer this question and to develop a promising prototype, with the support of Prof L'Her from Brest Regional University Hospital. The "non-invasive" ventilator designed by the robotics team is capable of falling into sync with the patient's breathing, so as to detect and adapt to their oxygen requirements.

[April-June 2020]



IETA MILITARY ENGINEERING STUDENTS WITH THE PARIS FIREFIGHTERS

Every year, the Paris firefighting brigade welcomes IETA military engineering officer cadets for their human and military training.

This year, these officer cadets were joined by volunteer 1st year IETA engineering students. They made a significant contribution. At the peak of the health crisis, in addition to the usual rescue & emergency missions, more than 2,500 calls and 500 interventions a day in Paris were to do with Covid-19.

[March-June]

MEMORABLE MOMENTS AND AWARDS

“What I have seen today, is the research excellence, especially in the field of underwater robotics, acoustics, the mechanics of materials and fluids and cybersecurity.”

Florence Parly, Minister for the Armed Forces, May 29, 2020



THE ENSTA BRETAGNE RESEARCH CENTER EXTENDS OVER 7,500 SQ.M. AND INCLUDES 3 DEPARTMENTS:

- **MECHANICAL SCIENCES:** 4,000 sq.m., some one hundred researchers, working in the Dupuy de Lôme Research Institute [IRDL] [joint research unit [UMR] of the French National Center for Scientific Research [CNRS] 6027, to which ENSTA Bretagne is the 2nd most prolific contributor).
- **INFORMATION & COMMUNICATION SCIENCE & TECHNOLOGY:** 3,000 sq.m., some one hundred researchers, working in the Lab-STICC [UMR CNRS 6285, to which ENSTA Bretagne is the 3rd most prolific contributor].
- **HUMAN AND SOCIAL SCIENCES:** 500 sq.m., some twenty researchers, working in the FoAP lab [Research Unit 7529].



RESEARCH CENTER EXTENSION, INAUGURATED BY THE MINISTER FOR THE ARMED FORCES

The 1,600 sq.m. building inaugurated by France’s Minister for the Armed Forces, Florence Parly, on May 29, rounds off the impressive experimental facilities devoted to the mechanical sciences on the ENSTA Bretagne campus.

ENSTA Bretagne’s research activities in partnership with industry and defense are aimed at predicting the in-service durability of mechanical structures and materials and at modeling hydrodynamic interactions and pyrotechnical phenomena.

ENSTA BRETAGNE IS NOW A PARTNER SCHOOL OF THE ÉCOLE POLYTECHNIQUE

Our original courses such as pyrotechnics, autonomous robotics, hydrography and naval architecture are of interest to students attending L’X, who can enroll in these programs alongside 3rd year students. For the school has joined the select circle of L’X partner schools for the “4th year” training of its students.



On February 13, 2020, conference given by Corentin Brustlein, Director of the Security Studies Center at the French Institute of International Relations (Ifri): “The United States’ defense strategy, from Obama to Trump”.

THE MINISTER FOR THE ARMED FORCES

showed a particular interest in the research conducted with the French Defense, Procurement and Technology Agency (DGA) and industry, including Thales, for the development of new naval mine warfare systems

These make use of a unique set of complex sciences and technologies, all found at ENSTA Bretagne: the design of autonomous marine and underwater drone systems for long-haul missions, their cybersecurity, new acoustic sensors and AI-based sonar image processing methods.

EXCERPTS FROM FLORENCE PARLY’S KEYNOTE ADDRESS:

“Safeguarding the operational superiority of our Armies tomorrow is a scientific, technological, technical, organizational and human challenge. And to take up these challenges, we will certainly need you.”

“You have a wealth of talent in your laboratories [...] That is why we have decided to strengthen the ties between your school and the Defense Innovation Agency. ” More particularly for our students, she had this to say: *“You are fortunate to be studying in a school that promotes dual activities (civil and military). Know that this is a strength, as it means you are doubling your field of vision and therefore your possibilities.”*

The quality of welcome for international students is recognized at the highest level.



DOUBLE DEGREE (DD) COURSES, WITH THESIS AT THE ECOLE POLYTECHNIQUE:

- **Maria Luiza Costa Vianna** (Brazilian): DD 2019 in "mobile robotics" ENSTA Bretagne / UFMG (Federal University of Minas Gerais) is working towards a thesis at the Ecole polytechnique on this theme.
- **Martin Avila Torrado** (Argentinian): DD 2018 in "mechanical modeling" ENSTA Bretagne / University of Buenos Aires, is working towards a thesis jointly supervised between the Ecole polytechnique TU Munich.



NEW INDUSTRIAL CHAIR OF THE FRENCH NATIONAL RESEARCH AGENCY (ANR): "SELF-HEATING", WITH NAVAL GROUP & SAFRAN

Led by ENSTA Bretagne (Dupuy de Lôme Research Institute) and two industry leaders, including the Institut P, the "Self-Heating" industrial chair has been accepted by the ANR. For four years, the teams will work on measuring the heat signature of materials for naval and air applications. The aim? Predict their in-service performance and fatigue life. The budget amounts to €2.05m, jointly funded by the ANR, Naval Group and Safran. This is the 1st ANR industrial chair in Brittany! Find out more on page 31

[Find out more on page 31](#)



NEW SPECIALIZED ADVANCED MASTER: PORT AND MARITIME SYSTEMS CYBERSECURITY

This program welcomed its first cohort in September 2020. Unique in Europe, it trains highly sought-after experts to counter the current attacks and detect future threats in the maritime sector.

This is a Specialized Advanced Master (equivalent of 6 years' higher education), accredited by the Association of Grandes Ecoles (CGE), and comprises one academic semester and one semester spent doing an internship. The course is taught by four prestigious engineering schools combining these specialist skills: IMT Atlantique, Ecole navale, ENSTA Bretagne and ENSM. It has received certification from the Pôle Mer Bretagne-Atlantique cluster and the Cyber Center of Excellence.

A STUDENT LIFE BURSTING WITH CREATIVITY

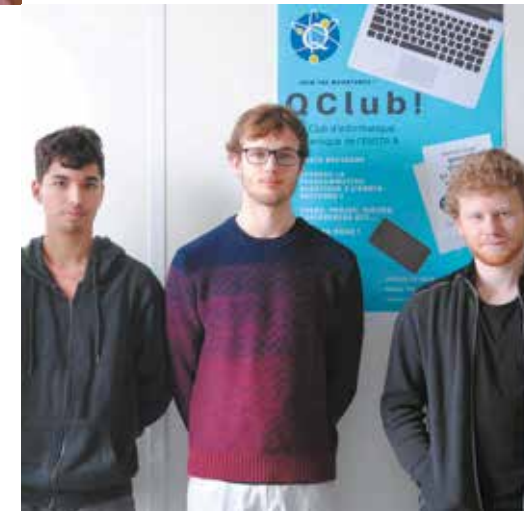
The lockdowns have not dampened the creativity of our students and clubs as nurturing ties

- Impact has scooped the national "junior-enterprise" label and provides an array of services.
- The new **Q club** gives an insight into quantum information science.
- **Kult'Art** brings together painting, decorative arts and design enthusiasts.
- The **digital interclubs** of the sports association are getting all their sports members moving – at home.
- The school now has its own **live-aboard sailboat**. In addition to the largest student sailing association in France, non-sailors can now also enjoy the thrills of sea outings too!



THEIR TALENT REWARDED

- **Break the code Challenge**
Five ENSTA Bretagne teams took part in the challenge organized by Sopra Steria: this was the 2nd time the Cyber club had participated ... and their 2nd victory!
- **"ActInSpace" hackathon.** Organized by the French space agency (CNES), the teams had 24 hours to tackle a space-themed technological challenge. 50 countries took part and 14 different cities in France. 5 students from the school who participated won 2nd prize in the event held in Brest.
- **"The passion for enterprise"**. At ITII Bretagne's 6th symposium, held online, the video pitch contest between 400 co-operative (apprentice) engineers from Brittany was won by the Hydrogénii/ENSTA Bretagne project.
- **2 students received accolades** at the French Society of Automotive Engineers (SIA) Trophy, see page 24.



A group of people, including a man and several women, are gathered on a boat. They are wearing outdoor jackets and scarves, suggesting a cool environment. The man on the left is wearing a blue jacket with a logo that includes the letters 'STA' and 'etage'. The women are looking at a small device or piece of equipment held by one of them. In the foreground, there is a large orange and white piece of equipment, possibly a motor or a sensor, mounted on the boat. The background shows a rocky shoreline and water. The overall scene suggests a field research or outdoor activity.

MISSIONS & AMBITIONS

AN ORIGINAL, PIONEERING SCHOOL

FOR THE DEFENSE, MARITIME AND INNOVATIVE INDUSTRIES

MORE THAN HALF A CENTURY OF HI-TECH AND INNOVATION

Steeped in 200 years' worth of training, ENSTA Bretagne is celebrating its 50th anniversary in 2021 (it was founded in 1971) and 30 years of research activities. The multidisciplinary school trains engineers and conducts high-level research for the most innovative industries and the defense sector.

- Initially dedicated to training Armaments Studies and Technology (IETA) Engineers for the French Defense, Procurement and Technology Agency (DGA), the school still carries out this essential mission to this day. It is the only engineering program awarding IETA status, rounded off by a course at the leading higher education provider for aerospace engineering, ISAE-Supaero, on aeronautics expertise.
- The innovative programs of the **defense industry** appeal to more than a third of young graduates – civil and military alike – every year. At ENSTA Bretagne's research center, studies are geared towards extensive applications in the military and civil sectors, including a large proportion in marine technologies, in which the school excels.

In the Top 25*
of France's graduate
engineering schools

The research is funded by the Ministry for the Armed Forces, local authorities and partner companies.

- More than 80% of students are in the civil stream, drawn by the cutting-edge training and wide-ranging employment sectors: **maritime, transport, energy, digital technology and aerospace.**
- Well established in its region, where it is the oldest engineering school, ENSTA Bretagne is set within a sweeping 7-hectare campus in Brest, right by the coast. It harbors significant teaching and research resources as well as all accommodation for students.
- Thanks to extensive cooperation with businesses and labs alike, both in France and abroad, high-level research and training and its diverse, original and complementary subjects, ENSTA Bretagne provides a hugely motivational setting for **preparing future engineers for the major challenges that lie ahead.**

ACCESSIBLE AND DIVERSE

970 students and PhD students

- 85% civil engineering students, 15% military engineering students
- 25 to 30% women
- 30% on grants or scholarships
- 20% international students

A dynamic network of

6,000 alumni

10 fields of excellence
in research and training

STRONG GROWTH MOMENTUM

For two decades, the school has been attracting a growing number of students, PhD students and high-level professors from all over France and beyond its borders.

- Students: x2 in 15 years**
- PhD students: x4 in 15 years**
- Number of graduates: x3 in 20 years**

PARTNER SECTORS



OFFSHORE,
NAVAL
INDUSTRIES
& ENERGY



DEFENSE
& SECURITY



INFORMATION
TECHNOLOGIES
& OBSERVATION
SYSTEMS



AERONAUTICS
& SPACE



AUTOMOBILE
INDUSTRY
& LAND
VEHICLES



TEACHING
& RESEARCH

* Source: SCEI 2020 (Engineering Graduate Schools' Entrance Examination Service)

OUR MISSIONS

Choosing to study, teach, innovate, and lead research at ENSTA Bretagne means choosing excellence, an open door to the world and access to an exceptional network of renowned hi-tech companies and scientific organizations.



TRAINING

ENSTA Bretagne trains general and high level specialist engineers who are immediately operational and have great potential. The quality of training at ENSTA Bretagne is renowned. Its graduates are rapidly recruited for the positions which interest them, in the most innovative of sectors.

ENSTA Bretagne graduates have various profiles, but one vocation which is to take part in innovative projects in design, R&D, measurements, tests or program management. They are prepared to evolve to face the major challenges of cutting edge industries and society, sustainable development, future transport, digitization, cybersecurity, maritime and space exploration...

ENSTA Bretagne is at the heart of an exceptional national and international network composed of hi-tech companies, academic institutions, civil and military test centers. Many double degrees enable the students to personalize their career paths and enhance their international prospects.

300
GRADUATES
IN 2020



3
TRAINING
AND RESEARCH
DEPARTMENTS

Mechanical Sciences
Information
& Communication
Human and
social sciences



19
TRAINING CYCLES

 pages 20 to 25



RESEARCH

A cornerstone for excellence in teaching, major multi-disciplinary research is carried out on campus, which is geared towards industrial, civil and military applications. The research programs are regional, national and international. The high-level scientific production is intense and constantly increasing, involving numerous partners.

ENSTA Bretagne research teams are assigned to multi-supervisory academic laboratories (IRDL, Lab-STICC, FoAP) and joint research structures with industry. The Research Institute has access to unique experimental facilities to characterize phenomena and validate scientific results, in mechanical sciences (the MASMECA technology platform) and information technologies (the Cyber Center, an anechoic chamber, the robotics pool, hydrographic vehicles, drone systems etc).

246
RESEARCHERS
ENGINEERS
TECHNICIANS
& PHD STUDENTS



3
ACADEMIC
LABORATORIES



8
CHAIRS
AND JOINT
LABORATORIES

 pages 28 to 45

INNOVATION

The implementation of scientific work and participation in strategic territorial planning have won ENSTA Bretagne an outstanding position in the socio-economic world. The creation of the ENSTARTUPS incubator and an impressive program of entrepreneurship awareness training have added to ENSTA Bretagne's innovation policy since 2017.

 pages 26 & 27





HYDROGRAPHY & OCEANOGRAPHY (CAT. A)



Brest is the birthplace of this discipline and ENSTA Bretagne is the only school where you can find French training in Category A Hydrography (the highest level awarded by the FIG-OHI-ACI) It is also one of the most renowned in the world.

Hydrography and Oceanography cover the methods used to describe and measure oceans, seas, lakes and water courses. This information is essential for all activities which are conducted at sea, around coasts or on rivers. 3 profiles are proposed:

- Hydrography
- Physical oceanography
- Marine geophysics.

The students have access to cutting edge equipment (a hydrographic survey vessel, amphibious vehicle, probes...), an environment which facilitates their application (the Brest Roadsstead, Lake Guerlédan) and a variety of projects (cartography, research on wrecks, dam inspections, etc...)

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training
- “Hydrography” Master (category A)
- Double Degree Research Master in “Marine Geophysics” or “Climate and Ocean Physics”
- Doctorate

THE LABORATORIES

- LAB-STICC Laboratory [UMR CNRS6285] cf. pages 36 to 43
- UMR Adaptation and Diversity in the Marine Environment [Station Biologique de Roscoff, CNRS / Sorbonne University]



AUTONOMOUS ROBOTICS



The scientific challenges are numerous: robot autonomy, coordination, stealth... Within this context of increased research and extremely diverse applications, the training provides the keys to designing, making, programming and testing autonomous and mobile robots, to carry out all types of missions on land, at sea and in the air.

Leading robotics projects requires many skills in:

- Mechanical design
- Signal detection and processing
- The use of multiple sensors
- Perception, artificial intelligence

Through combining telecommunications, digital circuits, computer science and security, ENSTA Bretagne-trained engineers and doctors are equipped with a set of skills sought after worldwide by industrialists in many sectors of activity and research laboratories.

OUR TRAINING COURSES

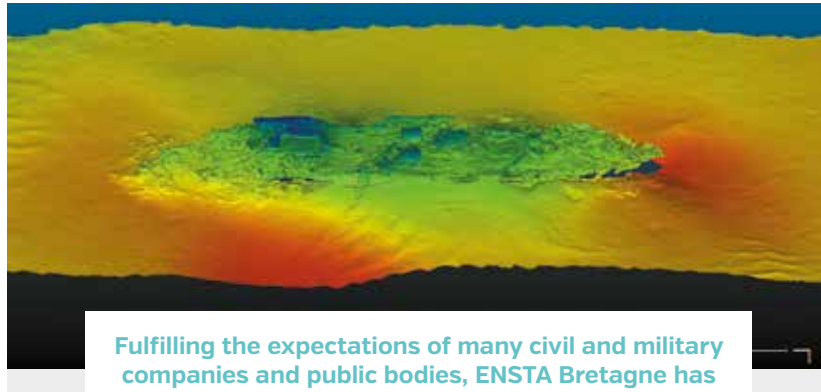
- Specialization in 2nd and 3rd years of general engineer training*
- Master in Mobile Robotics
- Doctorate

THE LABORATORIES

- LAB-STICC Laboratory [UMR CNRS6285] cf. pages 36 to 43
- Joint chairs and laboratories [with Thales and Naval Group]



OBSERVATION SYSTEMS AND ARTIFICIAL INTELLIGENCE



Fulfilling the expectations of many civil and military companies and public bodies, ENSTA Bretagne has amassed a broad range of expertise in the design of embedded systems, multi-sensor observation systems and advanced technologies of information processing for decision support.

To imagine and design tomorrow's embedded intelligence and observation systems, the training and research employs advanced techniques in artificial intelligence which answer the issues raised by heterogeneous and mass data acquisition, processing and analysis. It includes the modeling of physical phenomena, mono or multi-sensor systems experimentation and simulation, systems engineering, mastery of embedded observation systems, the analysis, processing and interpretation of data (signals, images...) as well as decision support (decision and estimation theory)

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training or co-operative (apprentice) engineer training in "Embedded Systems"
- "Multi-sensor and Localization Systems Engineering" Specialized Advanced Master
- Doctorate

THE LABORATORIES

- LAB-STICC Laboratory [UMR CNRS 6285] cf. pages 36 to 43
- Joint chairs and laboratories (with Thales and Naval Group)



SECURITY AND DIGITAL SYSTEMS



This expertise concerns the design of secure communicating digital systems, incorporating telecommunications, digital circuits, computer science and security [cybersecurity, reliability and protection of personal information].

NEW
The "Port and Maritime Systems Cybersecurity" Specialized Advanced Master opened at the beginning of the 2020 academic year (with IMT Atlantique, Ecole navale and ENSM).

The idea is to design the most reliable and long-lasting systems. Extensive research aims to develop high level, methodological approaches, based mainly on software engineering for embedded systems and model-driven engineering. In cybersecurity, ENSTA Bretagne brings students a complete overview, from the antenna and analog chain to threat analysis. The lessons cover the entire chain, software and material architecture modeling, the exploitation of sensor-derived information, setting up telecommunications, software development and ensuring system security from the design phase onwards

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training or co-operative (apprentice) engineer training in "Embedded Systems"
- "Architecture and Security of Software and Electronic Systems" Master
- "Computer Science" Master, "Autonomous and Intelligent Interactive Systems" option.
- Doctorate

THE LABORATORIES

- LAB-STICC Laboratory [UMR CNRS 6285] cf. pages 36 to 43
- Cyber Defense of Naval Systems Chair
- www.chaire-cyber-navale.fr



OFFSHORE AND NAVAL ARCHITECTURE



ENSTA Bretagne conducts the highest ranked training in France in offshore and naval architecture engineering and leads many research projects on the naval systems of the future, so that maritime transport is adapted for major challenges and more respectful of the environment.

With this exceptional training, the graduates design all types of vessels, submarines and naval platforms. All the parameters required for the optimum operation of a ship are taken into consideration: hydrodynamics, aerodynamics, durability, stability, propulsion, structural calculations, maneuverability, seaworthiness, ergonomics etc.

The research focuses on improving the performance of the ships, especially in terms of propulsion.

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training or co-operative (apprentice) engineer training
- "Maritime Engineering" Master
- "Naval Hydrodynamics" option
- "Marine Sciences" Master
- Offshore and Naval Architecture and Ship Design/Marine Engineering" Specialized Advanced Master
- Doctorate

THE LABORATORIES

- The Dupuy de Lôme Research Institute (IRD, UMR CNRS 6027) cf. pages 30 to 35
- Gustave Zédé Joint Laboratory (with Naval Group)
- The Chair of the French National Research Agency (ANR): "self-heating" (with Naval Group & Safran)



MARINE RENEWABLE ENERGIES (MRE)



Producing electricity from marine renewable energies (wind, wave, currents etc) depends on marine and su marine platforms which are innovative and resistant to the harsh conditions at sea. The training (which is unique in France) and research programs focus on their development.

One year of specialized advanced master (6 years post High School Certificate), 100% dedicated to MREs, trains engineers, future project managers or program directors. Accredited by the Conférence des Grandes Ecoles and endorsed by the Pôle Mer Bretagne Atlantique, it has brought together ENSTA Bretagne, Ecole navale, IMT Atlantique, UBO, Ifremer and companies. The school has produced over one hundred experts in 10 years, 90% of whom have joined the national and international MRE sector. With the *Institut pour la Transition Énergétique* "France Energies Marines" (the Institute for Energy Transition dedicated to Marine Renewable Energies), the research focuses on the mechanical behavior in situ of wind and wave turbines (resistance, materials, assemblies, blades, anchor lines, IMR vessels) and the modeling of the marine environment (currents and seabeds).

OUR TRAINING COURSES

- "Expert in Marine Renewable Energies" Specialized Advanced Master
- Doctorate

THE LABORATORIES

- The Dupuy de Lôme Research Institute (IRD, UMR CNRS 6027) cf. pages 30 to 35
- The Lab-STICC Laboratory (UMR CNRS6285) cf. pages 36 to 43

VEHICLE ARCHITECTURE



Long term partner of the automotive industry and the entire land vehicle sector, the school trains high-performing designers who are most respectful of the environment. Including applied research and a European master, engineers having followed this training have excellent career opportunities in France and abroad.

Starting from solid foundations in mechanical design, the students move on to the major issues of the sector such as environmental norms, and new motorization, the reduction of vehicle weight, reliability, active and passive safety systems, vehicle habitability, up to the qualification of dynamic performance.

The professors focus on fatigue, lifespan, deformation and the in-service behavior of materials and structures. This strategic research is geared towards validating choices made in terms of reducing vehicle weight and reducing consumption.

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training, or co-operative [apprentice] engineer training
- International Master in Automobile Engineering
- Doctorate

THE LABORATORIES

- The Dupuy de Lôme Research Institute [IRDL, UMR CNRS 6027] cf. pages 30 to 35
- OpenLab "Computational Mechanics" [with the PSA Group]

ADVANCED MODELING OF MATERIALS AND STRUCTURES



Using new materials and assembly techniques is a growing trend. This involves solving the complex sizing challenges required for many activity sectors where the highest level of mechanical performance is crucial: aeronautics, the naval and automobile industries, energy, defense, the biomedical industry etc.

Optimization through modeling is necessary in all fields, to reduce the environmental footprint of human activities, to adapt to new norms, or to seize opportunities and develop new markets (new materials, innovative procedures, new energies etc).

These courses are based on high-level research aiming to characterize and model the mechanical properties of all types of materials and structures. This applied research is carried out in close collaboration with numerous industrialists. Under these conditions, the use of comp sites, light alloys, biomaterials and adhesively-bonded structures can become more commonplace.

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training
- "Design Engineering" Master, "Mechanics, Materials and Civil Engineering" option
- Doctorate

THE LABORATORIES

- The Dupuy de Lôme Research Institute [IRDL, UMR CNRS 6027] cf. pages 30 to 35
- Gustave Zédé Joint Laboratory [with Naval Group]



PYROTECHNIC SYSTEMS



Unique in France, this training dedicated to pyrotechnics focuses on the analysis and design of explosive systems and their integration into mechanical systems

Mastering explosive effects and designing propulsion systems can only be achieved through the acquisition of high level expertise. Many activity sectors are concerned: defense, the aerospace and automobile industries, public works or even the prevention of industrial hazards. The innovations concern energetic materials which are safer for their users, as well as the attenuation of blast effects. These dominant trends form part of the syllabuses and are the subject of research on campus. ENSTA Bretagne has extensive experimental facilities dedicated to the study of dynamic phenomena: shock wave propagation, combustion, blast effects, impacts etc.

OUR TRAINING COURSES

- Specialization in the 2nd and 3rd years of general engineer training
- "Pyrotechnics and Propulsion" Specialized Advanced Master
- Doctorate

THE LABORATORIES

- The Dupuy de Lôme Research Institute (IRDL, UMR CNRS 6027) cf. pages 30 to 35



ENGINEERING AND BUSINESS SCIENCE



As a complement to the engineering sciences and core subjects in Human Sciences, this trains managers, project leaders and entrepreneurs.

NEW COURSE
Ship maintenance
 with the Ecole navale, associated with the Specialized Advanced Master in "Maritime Project Management" (September 2021).

This specialization in management opens up a wider range of responsibilities in companies or public bodies for the graduates. It encompasses business engineering, project, innovation, performance and intercultural management in an international context. Other students choose a one year course dedicated to maritime project management, which encompasses the concept of a maritime project, the management of an international team, quality evaluation and the management of partnerships. Innovation training is also an original research field at ENSTA Bretagne, including the study of French and international curricula used to train tomorrow's innovators.

OUR TRAINING COURSES

- Specialization in the 3rd year of general engineer training or co-operative (apprentice) engineer training
- "Maritime Project Management and Ship maintenance" Specialized Advanced Master
- Doctorate

THE LABORATORIES

- The "Formation et apprentissages professionnels" (Professional Apprenticeship and Professional Training) Research Unit (FoAP, EA 7529) cf. pages 44 & 45

GLOBAL STANDING

"Because interculturality is a factor for progress, an international outlook is built into ENSTA Bretagne's DNA, across all of its activities: double degrees, personalized semesters in the very best partner universities, internships, jointly supervised theses and more..."

Because ENSTA Bretagne sets meaningful store by excellence, we develop both academic and scientific collaborative projects with the foremost labs and establishments in our fields of expertise.

This policy also enables us to welcome the very best international students, who have often been awarded scholarships of excellence and whose participation on-campus perfectly captures the intercultural mindset that prevails here".

Hélène Guillaumot,

Director of International Development and Partnerships

EXAMPLES OF ACADEMIC PATHWAYS

GERMANY: **Stefanie Schwartz** [2021 cohort] in her 2nd year of the *Hydrography Master*, after a BSc in *Physics of the Earth system* from Kiel University.

AUSTRALIA: **Krzysztof Borkowski**, after a BEng in *Mechanical Engineering*, in 2020 he was awarded the double-Master's degree *Surface ships and submarines* with the University of Adelaide [UoA].

CAMEROON: **Manuella Feunkeu Mfupa** graduated in engineering in 2020 in the "observation systems and perception" major, after a Master in "Mechanical modeling and vibration" from Le Mans University.

ITALY: **Giovanni Gamba**, student at Politecnico di Milano, on an Erasmus+ exchange program for one semester; he is studying for a Master in *Mechanical Engineering* [2022 cohort].

LEBANON: **Nour Bahlak**, student at the Lebanese University – Faculty of Technology, with an EIFFEL scholarship of excellence, is taking an engineering double degree in the "digital systems & security" major [2021 cohort].

93

PARTNERS

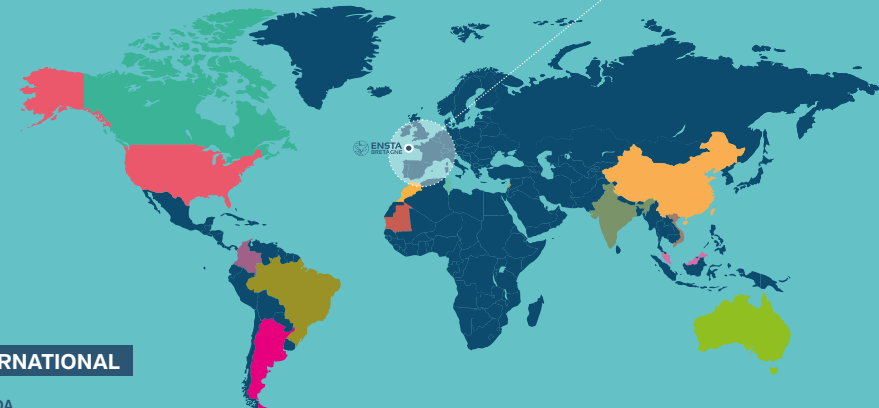
ACROSS **26** COUNTRIES
+ A HOST OF SCIENTIFIC
PARTNERSHIPS

45

INTERNATIONAL
MSC COURSES ON A
DOUBLE-DEGREE BASIS

EUROPE

- UNITED KINGDOM > CRANFIELD
Cranfield University...
- BELGIUM > LIEGE
Université de Liège
- NETHERLANDS > DELFT
TU Delft
- SPAIN > BARCELONA
Universitat Politècnica de Catalunya
- PORTUGAL > PORTO
Faculdade de Engenharia
da Universidade do Porto de Catalunya
- POLAND > GDANSK
Gdansk University of Technology...
- GERMANY > CHEMNITZ
Technische Universität Chemnitz...
- CZECH REPUBLIC > PRAGUE
CZECH Technical University [CTU]...
- ROMANIA > BUCHAREST
Academia Technica Militara Bucarest...
- ITALY > MILAN
Politecnico di Milano



INTERNATIONAL

- CANADA
HALIFAX : Dalhousie University
RIMOUSKI : Université du Québec [UQAR]
- UNITED STATES
CHICAGO : Illinois Institute of Technology [IIT]
ATLANTA : Georgia Institute
- COLOMBIA
BOGOTA : Universidad de Los Andes
of Technology [Georgia Tech]...
FORT COLLINS : Colorado State University
- ARGENTINA
BUENOS AIRES : Universidad de Buenos Aires...
- BRAZIL
RIO DE JANEIRO : Universidade Federal
do Rio de Janeiro
PORTO ALEGRE : Universidade Federal
do Rio Grande do Sul...
- MOROCCO
RABAT : École Mohammadia d'Ingénieurs
- SENEGAL
DAKAR : Ecole Supérieure Polytechniques
- TUNISIA
SFAX : Université de Sfax
- LEBANON
BEYROUTH : Lebanese university...
- INDIA
CHENNAI : Indian Institute of Technology
Madras [IITM]
GOA : IIT Goa
- VIETNAM
HO CHI MINH :
University of Sciences [HCMUS]
- AUSTRALIA
LAUNCESTON : University of South Australia
ADELAIDE :
• I'UoA (University of Adelaide)
• Flinders University
- CHINA
QINGDAO : Ocean University of China
SHANGHAI : Tongji University...
- MALAYSIA
KUALA LUMPUR : Universiti Teknologi
Malaysia [UTM]
PENANG : Universiti Sains Malaysia
Engineering Campus

> Complete list of international partnerships:

www.ensta-bretagne.fr/partenaires-academiques-internationaux
www.ensta-bretagne.fr/doubles-diplomes-internationaux

EVERY YEAR

150

ENGINEERING
PROJECTS

Accomplished by groups
of students on themes

Connected to industry
and public works



Video of industrial project
viva voces
bit.ly/ProjetsIndus2A



450

ENGINEERING
INTERNSHIPS
3 to 6 months



>1000

COMPANY
PARTNERSHIPS
IN FRANCE
AND WORLDWIDE



**RARE EXPERTISE
IN CONTINUING
PROFESSIONAL
DEVELOPMENT**

List of internships at:
ensta-bretagne.fr/formation-continue

A SCHOOL GEARED TOWARDS HI-TECH COMPANIES

There is considerable industrial collaboration in terms of training, CPD, research and innovation. This guarantees that our training programs are fully in line with businesses' expectations, that our graduates quickly find work and that a meaningful balance is struck between fundamental and applied research.

IN TERMS OF TRAINING

- Provision of engineers and experts for the courses or exam juries
- Presence at careers fairs
- Study and design subjects proposed to the teachers to lead group and mentored projects, in the 2nd and final year (MSc level)
- Assistant engineer internships (3 to 5 months) or final year projects (5 to 6 months)
- Professionalization contracts
- Co-operative (apprenticeship) contracts
- Staff training for companies

IN TERMS OF RESEARCH

- Research contracts
- CIFRE Theses (Conventions Industrielles de Formation par la Recherche, an industrial "training through research" agreement)
- Tests and measurements
- Joint laboratories
- Research chairs

SCHOOL LIFE

- "God parenting" (patronage) of a cohort
- Participation in governing boards, training, research, and company relation committees
- Financial support: apprenticeship tax, ENSTA Bretagne scholarship, sponsoring of student projects



OCTOBER 2020

Antoine Bouvier, Head of Strategy, Mergers & Acquisitions and Public Affairs at Airbus, "godparent" of the 2021 cohort:

"The aeronautical and defense sectors have great expectations as regards the expertise that your engineers have to offer. Our industry is going through a period of radical change and now, more than ever, we need the skills that you have to offer in the fields of pyrotechnics, advanced modeling of materials and structures, observation systems, embedded systems and artificial intelligence. These are essential skills that enable companies such as Airbus to remain competitive on the international scene."

+ www.ensta-bretagne.fr/en/godparenting-2021-cohort

2021/2022 corporate calendar
www.ensta-bretagne.fr/brochure-entreprises-fr



THE MINISTER FOR THE ARMED FORCES

has tasked ENSTA Bretagne with organizing a research network dedicated to the maritime sector, bringing together different academic partners, including IMT Atlantique, Ecole navale and the French Naval Hydrographic and Oceanographic Service (Shom).

ENSTA BRETAGNE ALUMNI

an active network of 6,000 former students, run by volunteers and chaired by Pierre Faucoup, CEO of Cilas.



ENSTA BRETAGNE IS PART OF THE INTERDISCIPLINARY GRADUATE SCHOOL FOR THE BLUE PLANET (ISBLUE)

This is the French research university dedicated to marine science & technology.
360 Master's students,
260 PhD students

OUR PARTNERS AND NETWORKS

In both training and research, ENSTA Bretagne has developed close relationships with many public and private bodies. The school is at the heart of a vast network of companies, competitiveness and other clusters, laboratories, universities and graduate engineering schools.

SUPERVISION

ENSTA Bretagne is part of the group of graduate schools under the supervision of the **DGA (Direction Générale de l'Armement or French Technology and Procurement Agency)**, part of the French Ministry of Armed Forces, together with the Ecole Polytechnique, ISAE-Supaero and ENSTA Paris.

The ENSTA Bretagne-led training programs, research and innovation, some of which are covered by agreements with the **Defense Innovation Agency (AID)**, contribute to the wealth of expertise at the French Defense, Procurement and Technology Agency (DGA) and, more broadly, the whole of the Ministry for the Armed Forces and its industrial partners.

Every year, ENSTA Bretagne recruits and trains 43 Armaments Studies and Technology (IETA) Engineers, who have a key role to play within the latter Ministry in planning, implementing and supporting the flagship armaments programs.

PARTNER GRADUATE SCHOOLS

Apart from its international partners [cf. page 12] and its research laboratory partners [cf. pages 33 to 51], ENSTA Bretagne proposes various academic paths for its students, as a gateway to double degrees or other courses at our partner graduate schools: IMT Atlantique, ENSTA Paris, ISAE-Supaero, ENSG, ENS Cachan, INSTN, the Polyméca network, IAE Brest, Audencia, ENSA Paris La Villette graduate school of architecture... united by the same exacting standards as ENSTA Bretagne.



Visit from Cécile Sellier, DGA/DT Director [December 2020]

INNOVATION AND ECONOMIC DEVELOPMENT

ENSTA Bretagne plays an active role in many civil and military innovation programs and the strategic planning which defines them. The school is involved on an international, national, regional and local level.

- **Competitiveness clusters:** Pôle Mer Bretagne Atlantique (maritime economy), ID4CAR (automobile), Images et Réseaux, EMC2 (future manufacturing technologies), Aerospace Valley
- Institut pour la Transition Énergétique (ITE) **France Énergies Marines** (marine renewable energies)
- Institut de Recherche Technologique (IRT) **Bcom** (digital innovation).
- **ORION** innovation cluster in naval defense
- Pôle d'Excellence Cyber (**PEC**) cyber excellence cluster
- "Laboratoire d'Excellence" **CominLabs** on information and communication sciences
- **Bretagne Télédétection Scientific Interest Group** (GIS BreTel) on space applications and technologies.
- **Local action** with the Campus Mondial de la Mer, the Technopôle Brest Iroise (non-profit organization), Brest Metropole and Region of Brittany.



TRAINING

EDUCATION TRAINING

Adapting to safeguard the value of our programs and the success of our students

Throughout 2020, all of our teaching staff showed a sense of responsibility in promptly rallying to protect the physical and mental health of our students, and to tailor teaching methods and the organization of classes. It is a source of great pride for me to observe that these goals have been achieved. But the constantly changing health situation means that this immensely trying challenge is far from over.

Much more than in previous years, course material has had to be revised and teaching techniques reconsidered constantly in an effort to reinvent them. In order to manage these changes seamlessly, solidarity and mutual support have proved invaluable. The school has also heavily invested in distance learning tools and in the virtualization of information systems.

Thanks to the school's adaptability and caring attitude, contact has been maintained with all of our students, whose motivations and difficulties have been heeded on a weekly basis. All foreign students continued to be welcomed, whether on-campus or online, and close, ongoing follow-up was ensured of all our students engaged in international mobility. In addition, young graduates from the 2020 cohort have been given more guidance in finding their first job, thanks to our close links with the network of alumni.

With their academic routines completely upended, our students have also had to adopt new methods at a moment's notice. They have had to demonstrate resilience both in their social and extracurricular lives, as well as in their academic motivations and ambitions, particularly amid the cancellation of their trips abroad. There have at times been bitter disappointments, and yet the students have unwaveringly helped each other out, kept in touch and showed an admirable cohesion as a cohort. As such, despite the regular sense of weariness, their determination to succeed has held strong, thanks to the encouragement and support of their dedicated teaching staff and the school as a whole. The value of our pro-

grams and the academic success of our students, which we have kept a constant eye on, have not been called into question.

The year was noteworthy in many other respects too. It confirms the very high level of student recruitment, whether through the "Mines Télécom" entrance exam in which ENSTA Bretagne leads the way, or through application-based admissions, for which the number and quality of applications continue to grow.

Our inclusion as one of the select partner schools of the Ecole Polytechnique is a glowing example of this: ENSTA Bretagne enjoys a highly reputed profile.

The range of CPD options is continuing to grow with, last September, the launch of a Specialized Advanced Master in Port and Maritime Systems Security and the setup of a new co-operative program for international military engineering students.

The school also expertly prepared the groundwork for the end-of-year audits performed by experts from the CTI and HCERES.

The auditors commended the all-round dedication and professionalism. The engineering training programs, whether taken with student or co-operative (apprentice) engineer status, are well-respected in the corporate world and have been put forward for accreditation again. A significant change this year is that the apprentice engineering program has branched out into two qualifying streams, focusing on their specifics in naval architecture and vehicles on the one hand, and embedded systems on the other.

2020 will certainly be remembered, and come to symbolize our school's ability to invest and reinvent itself as often as necessary. I should like to thank the course leadership teams, who remain committed alongside students and faculty alike and are working hard to improve the quality of service, tirelessly and with a ready ear.

Continuing to move forward and plan for the future



Rémy Thibaud
Dean of Faculty

TRAINING ENGINEERS AND EXPERTS

Train engineers
and experts

FIGURES AT THE START OF THE 2020 SCHOOL YEAR

GENERAL ENGINEER PROGRAM

3 year curriculum, accredited by the CTI* (bac+5)

ENSTA Bretagne delivers high-level multi-disciplinary training, in response to major societal and technological issues. The graduates are highly sought after by companies in France and abroad. They are immediately operational in the chosen field of expertise and able to evolve and rapidly take on responsibilities.

CORE CURRICULUM

- General, complete and balanced education
- Mathematics, information technologies, digital sciences, mechanical sciences, human sciences, intercultural management, societal challenges...
- Numerous implementation projects with companies
- Workshops, company simulations, leadership internship...

9 SPECIALIST FIELDS TO CHOOSE FROM

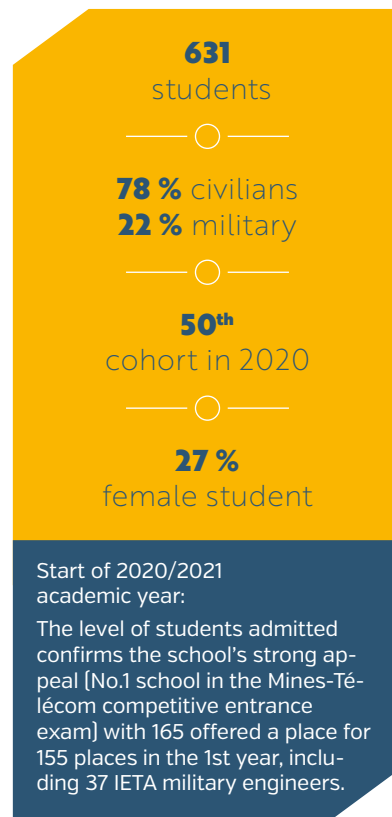


PROFILES

- Studies and Design, R&D, assessment, tests and measurements engineer
- Armament engineer
- Research engineer
- Business engineers
- Entrepreneur engineers

ADMISSION

- After scientific preparatory classes, and the Mines-Telecom competitive entrance examinations: 155 places
- Or university graduate (L3,M1,M2) and application dossier(L3, M1, M2).



ENGINEER TRAINING APPRENTICE

3 year course, delivered with companies, endorsed by the CTI* (bac+5)

A multi-disciplinary and demanding education program, mixing lessons with practical periods in companies, enabling high-potential students, mostly with technological training backgrounds [DUT, BTS] to attain the best level. The quality of the first 10 cohorts established the reputation of the training. The school is increasingly solicited by high-performing candidates

- 100% of time spent training
- 40% academic sequences
- 60% professional sequences

CORE CURRICULUM

- General, complete and balanced education
- Mathematics, information technologies, digital sciences, mechanical sciences, human sciences, intercultural management, societal challenges...
- Thesis and viva voce on technical themes or business culture after each professional sequence

4 SPECIALIST FIELDS TO CHOOSE FROM

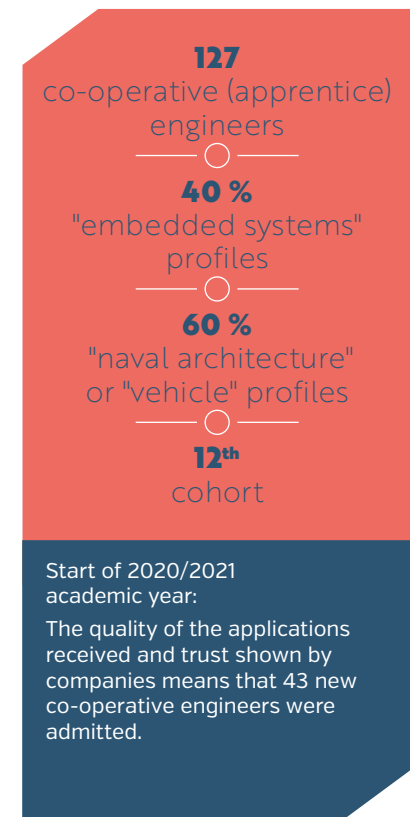


PROFILES

- Research engineer, design, R&D, testing and measurements
- Business engineer
- Engineer contractor

ADMISSION

- After a technical degree, 2 year post high school certificate diploma, via a dossier and interview: 50 places



* CTI: Commission des Titres d'Ingénieur. In France, the CTI is the relevant body in charge of carrying out evaluation procedures that lead to the accreditation of the institutions to award the engineering degree.



EMPLOYMENT SURVEY COHORT 2019



In all the special subjects, the rapid integration into the world of work of the young 2019 graduates and the increase in the average salaries confirms the reputation of the school in the business world and how the profiles of the students are a match for the challenges which await them.

298
GRADUATES
INCLUDING **244**
ENGINEERS

97 %
NET EMPLOYMENT
RATE AT 6 MONTHS
national average: 90%

12 DAYS
AVERAGE TIME
TO FIND
A FIRST JOB

€ 39800
AVERAGE GROSS
ANNUAL SALARY

Study representativeness: 100%. Annual national survey conducted by the Conférence des Grandes Écoles at the beginning of 2020, of 2019 graduates 6 months after graduation.

MASTERS

2 year course, accredited by the French Ministry for Higher Education, Research and Innovation

6 MASTERS OF WORLDWIDE RENOWN

- **HYDROGRAPHY***
(category A of the international organization FIG-OHI-ACI). Carry out and assess hydrographic surveys according to the international norms for the sector
- **MARITIME ENGINEERING**
design all types of naval systems, ships, platforms and submarines. This is associated with the MSc of Marine Engineering of the University of Adelaide (UoA) for the Franco-Australian double degree "Ships and Submarines**"
- **MOBILE ROBOTICS**
Dedicated to the design and creation of mobile robotic systems, this includes the material and software
- **AUTOMOBILE ENGINEERING***
Unique in Europe, this international program associates 5 establishments in 5 countries: ENSTA Bretagne, the University of Prague (CTU), the University of Arnhem (HAN), the University of Chemnitz (TUC) and the University of Bandung (ITB)

ARCHITECTURE AND SECURITY OF ELECTRONIC SYSTEMS AND SOFTWARE

This answers all the challenges of secure communicating systems: modeling software and material architecture, exploiting information provided by sensors, installing telecommunications...

JOINTLY-ACCREDITED MASTERS

- **"Marine Sciences" Master** (with UBO/IUEM)
 - **NAVAL HYDRODYNAMICS** option
 - **OCEAN AND CLIMATE PHYSICS** option (coastal, offshore and ocean data sciences)
 - **MARINE GEOPHYSICS** option
- **"Design Engineering" Master, MECHANICS, MATERIALS AND CIVIL ENGINEERING** option (with UBO, UBS, ENIB and INSA Rennes)
- **"Computer Science" Master, INTERACTIVE, INTELLIGENT AND AUTONOMOUS SYSTEMS** option (with UBO, ENIB and IMT Atlantique)

38
students

plus military students trained under contracts with foreign armies.

SPECIALIZED ADVANCED MASTERS (MS)

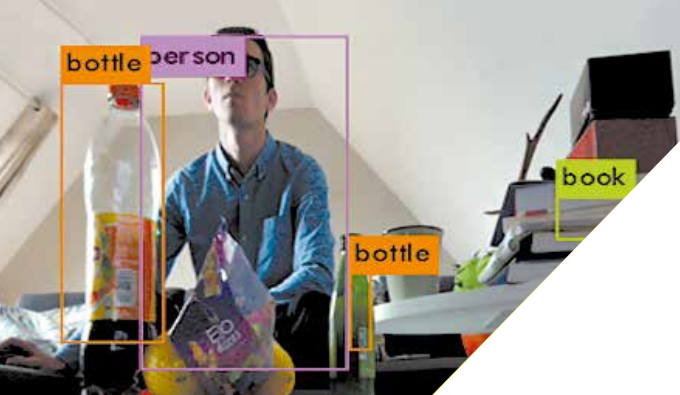
1 year course, accredited by the Conférence des Grandes Écoles

INTEGRATE HIGH TECHNOLOGY SECTORS OF THE FUTURE

- **CYBERSECURITY OF PORT AND MARITIME SYSTEMS***
New for the 2020 academic year
Counter current attacks and detect future threats to defend and operate specific maritime and port systems (training endorsed by the Pôle Mer Bretagne Atlantique quality label)
- **MARINE ENGINEERING, OFFSHORE AND NAVALARCHITECTURE, AND SHIP DESIGN***
Train to become a naval architect, project leader, studies engineer, research engineer or shipyard manager. This is associated with the DPEA of the ENSA Paris La Vilette School of Architecture for the "Ship Design" option
- **MARINE RENEWABLE ENERGIES (MRE) EXPERT***
Design systems to harness MREs, analyze the impacts and the issues, manage MRE programs
- **MANAGEMENT OF MARITIME PROJECTS***
Manage, coordinate and evaluate maritime projects of international caliber (training endorsed by the Pôle Mer Bretagne quality label)
- **PYROTECHNICS AND PROPULSION***
Master the physical phenomena of combustion, deflagration and detonation and integrate them into a mechanical propulsion system
- **LOCALIZATION AND MULTI-SENSOR SYSTEMS ENGINEERING*** (with ENSTA Paris). Design multi-sensor technological initiatives

49
students

***MOST OF THESE COURSES ARE UNIQUE IN FRANCE**



TRAINING PROGRAM PROJECTS

Teaching through projects is a fundamental part of our training programs

EXAMPLES OF DELIVERABLES OF THE 2021 AND 2022 COHORTS

This has been part of the fabric of the school since its very beginning. The many implementation projects led help the students to acquire a system view.

These simulations enable them to progress rapidly on the most complex problems, and to be immediately operational at the end of their studies.

The group implementation projects are on real company subjects or inspired by the latest issues and are supervised by the professors during semesters 3, 4 and 5.

They enable students to study and create complete deliverables in the 10 fields of expertise of the school.

- **Cybersecurity** / "Goldorak" project

On robotized arms representing an industrial assembly chain, a co-simulation approach has been developed to detect cyberattacks. This included the deployment of sensors, development of scenarios, injection of flaws and remote monitoring via PCs or smartphones.

- **Secure observation systems** / "SPOLIVA" project with KEREVAL

This was conducted as part of the KER-SEVECO project on the cybersecurity of embedded systems in smart vehicles. The aim? To demonstrate that LIDAR is vulnerable to attack and to come up with a hardware and software solution (a demonstrator) for detecting and diverting such attack types (e.g. jamming system). The solutions were able to be tested.

- **Embedded systems** / "Deepdart" project

Two co-operative [apprentice] engineers, Tony and Théo, worked on AI-based robot recognition. Their project entailed several phases: learning (12,000 images were added to the database; supercomputer), running of the image analysis algorithm and detection (an algorithm reworks the image).

- **Hydrography and robotics** / "Ulysse: USV-led autonomous bathymetric survey" photo (photo)

Roboticians and hydrography students work together every year on projects tested at Lake Guerlédan. One group has devoted its attention to Ulysse, an autonomous catamaran. By the end of the project, Ulysse was capable of scanning an area, detecting an error in a bathymetric sur-

vey in real-time and going back over the location where the errors had been identified. Ulysse offers up new potential: marine mapping of non-navigable, shallow or at-risk areas.

- **Mechanical design** / Thales project: "towed sonar recovery/deployment"

27 designs were devised in 2019 by various teams. A 28th team then came up with a final design bringing together the very best ideas. This was pre-sized, CAD-modeled and delivered to Thales.

- **Mechanical design** / "testbed for mooring chain wear".

In conjunction with a thesis under study at the school (in the IRDL lab, with: CEREMA, Phares et Balises, the French Navy and chain manufacturers Marit and Carlier), the testbed will be used to reproduce the wear phenomena of submerged chains, under laboratory conditions, by defining a certain number of parameters. Following the 27 designs put forward by the teams, a new project will work on designing the "best" testbed through a recap of the previous ideas.

- **Vehicle architecture** / hybrid

"What hybrid architecture and what control for a 44-ton long-haul truck?" (SIA 2020 trophy: French Society of Automotive Engineers). In response to the specifications defining the characteristics of a hybrid truck that must achieve "0" CO2 emissions during urban deliveries, the students scooped 2nd prize.



EXAMPLES OF END-OF-STUDIES PROJECTS UNDERTAKEN BY THE 2020 COHORT

The best end-of-studies projects in naval architecture, hydrodynamics, ship design and MRE.

- **Paul BUHNEMANN** [Marine Engineering/Naval and Offshore Architecture Specialized Advanced Master]: end-of-studies project at Marine Assistance, on the design of a support vessel for offshore wind farms..
- **Sinéad WEGELER** [Marine Engineering/Naval and Offshore Architecture Specialized Advanced Master]: end-of-studies project at EFINOR Sea Cleaners, on the design of a marine waste recovery vessel.
- **Paul RENAUD** [engineering student, naval architecture major]: end-of-studies project at Thales DMS, for the design of a maneuverability model for drone recovery.
- **Thibault LECARPENTIER** [co-operative engineer, apprentice at Naval Group]: end-of-studies project on the production and consolidation of weight estimation (contribution of equipped methods).
- **Juliette LEPROU** [ENSTA Bretagne 2019 engineer, major in the "Expert in Marine Renewable Energies" Specialized Advanced Master 2020]: end-of-studies project at Principle Power, project development as part of the "Kincardine" program on floating offshore windfarms, off the Edinburgh coast in Scotland.
- **Johan DAELMAN** [ENSTA Bretagne 2015 engineer, "Expert in Marine Renewable Energies" Specialized Advanced Master 2020 graduate]: end-of-studies project at Quadran Energies Marines, on preparation of the 2021/2022 "floating windfarm" calls for tenders and the setup of a hydrodynamic computational chain.

The ATMA prize for the best maritime project: hydrography-oceanography given pride of place.

The top five end-of-studies projects are nominated for the 2020 prize, all in connection with key challenges for protecting our environment.

- **Solène DÉALBÉRA** engineer, end-of-studies project at LEGOS in Toulouse): "Main risk of coastal flooding at global level: land subsidence or rising sea levels?". This is about gaining a clearer understanding of the phenomena behind coastal flooding, which takes a steep toll in terms of human life and property damage.

- **Rémi GIRARDON** (ingénieur, PFE à l'université de La Rochelle) : « *Modélisation numérique Barocline et multi-échelle de la côte des Pertuis Charentais* ». Il s'agit d'améliorer la manière de prendre en compte le déversement des fleuves dans un modèle océanique côtier. Ces modèles permettent de mieux appréhender la circulation hydrodynamique dans les zones estuariennes afin, par exemple, d'étudier l'impact de pollutions.
- **Pierre-Antoine LAMER** Rémi Girardon (engineer, end-of-studies project at La Rochelle University): "Multi-scale and baroclinic digital modeling of the Pertuis Charentais coast". The purpose is to improve consideration of river flows in a coastal oceanic model.
- **Pierre-Yves L.** (IETA military engineer, end-of-studies project at IFREMER in Brest): "Geomorphological mapping of the Channel seafloor and the northern part of the Bay of Biscay: automated morphological analyses from digital bathymetric field models
- **Alicia MAURICE** (engineer, end-of-studies project at EDF DTG): "Optimization of velocity measurements in river and coastal hydrography". The techniques studied pave the way to optimized velocity measurements when acquiring and processing river and coastal hydrographic data, so improving the quality of bathymetric surveys in these areas.

The best end-of-studies projects in IT, mechanical sciences and business science

Robotics / autonomous parachute

- **Kevin B.** (ingénieur IETA, PFE à l'AID) : « *Conception et réalisation d'un parachute autonome* ». Partant de zéro, un tel système devait être modélisé, simulé et construit. Différents algorithmes de navigation ont été développés, ainsi qu'un estimateur permettant de mesurer le vent en vol. L'intégration de ces éléments a abouti à la réalisation d'un premier prototype pour lequel il a été nécessaire de choisir les capteurs, les actionneurs et le microcontrôleur. youtu.be/L04n5RVhgAc

Advanced modeling of materials and structures

- **Arthur PELTRE** (end-of-studies project at EDF): "Comparison of seismic sizing methods for forklifts". Following this commendable project, the student was hired on a permanent contract as a design engineer at Edvance (subsidiary of EDF and Framatome).

Vehicle architecture

- **Antoine BOURASSEAU** (end-of-studies project at Renault Trucks): "Design of a rear drive unit for electric HGV". The young graduate is now on a permanent contract as a design engineer at Goupil (electric utility vehicles).

Pyrotechnics / laser propulsion for deviation of asteroids and space debris

- **Aurihona WOLLF** (engineer, end-of-studies project at the CEA): "Study of the momentum transmitted by laser ablation and fragmentation". After taking a gap year at NATO, her final study semester at ENSTA Bretagne together with a research Master [ISAE-ENSMA] and jointly wri.

Observation systems and AI / medical imaging

- **Amadou Sall** (engineer, after an end-of-studies project at the Biomedical Imaging Laboratory [LIB], Sorbonne University, where he is working towards a thesis): "In vivo ultrasound imaging of the femur bone". A different approach to physics which has enabled imaging of the inside of the cortical bone for the first time by ultrasound scan.

This project showed that, via a change in signal processing, the quality of the images and diagnosis are improved to assess bone deterioration. On the basis of a detailed study of the physical and digital model, the most suitable simulation tool for bone tissue, an elastic and porous environment, could be chosen.

Engineering and business science / IT project management and remote working

- **Alexis Baulu** (engineer, end-of-studies project then permanent contract at Dassault Systemes, as "Finance BTC Business Process Analyst") changed his end-of-studies project topic in light of the crisis: he deployed "Planning Analytics", managed the project, supported users and built a "Workload Management" application program. The crisis that unfolded from March 2020, bringing lockdown and remote working in its wake, prompted him to propose this social tool for the benefit of project management.

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head of entrepreneurship
& ENSTARTUPS
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ENSTARTUPS ENSTA BRETAGNE'S INCUBATOR



The ENSTARTUPS incubator promotes entrepreneurship and supports creators

Created in 2017, the ENSTARTUPS incubator aims to help people with projects in the idea stage by advising them through all the stages in company creation. It is continuing to develop and receive new projects.

Antonin Raffarin, head of ENSTARTUPS:

"The creation phase is the deciding moment for these entrepreneurs. We validate all the stages beforehand, so that the creation and rest of the adventure can continue in the best of all possible conditions. At the same time, failure or abandonment are also part of the life of a startup project. Two projects decided to give up on their entrepreneurial adventures due to failure to find a market".



11

START-UPS
IN CREATION IN 2020



4

COMPANIES
CREATED

NEW PROJECTS

- **YMADE** : electric motorbike made out of wood, by a co-operative (apprentice) engineer
- **OX-EYE** : naval architecture & engineering agency [<http://ox-eye.com/>], by a former student
- **ARKANE** : radar signal and AI processing (for 5G, the IoT, space, etc.), **winner of the "Launcher of the future" challenge (CNES)**.
- **SEEDERAL** : design of an electric tractor

IN INCUBATION

- **SPLASHELEC** : two projects: "make sailing accessible to abeginner" (sailing via a joystick) and "foil actuation project".
- **TRASH SURFBOARD** : "surfboards based on recycled cardboard"; creation of the structure.
- **ORPHIE** : "improving underwater camera vision"; prototype finished, seeking an industry to test it.

FAST-GROWING STARTUPS

- **FIL&FAB** : "fishing net recycling", production methods deployed [www.fil-et-fab.fr].
- **UMOJA** : "African fabric footwear", marketed [www.umoja-shoes.com].
- **GWILEN** : "marine sediment recovery", currently available for pre-order [www.gwilen.com].
- **IANIRA** : "marker for divers", equipped with a system designed and patented by ENSTA Bretagne, currently being marketed.

Yann Morin, an apprentice engineer, has just joined the incubator and designed a ground-breaking electric motorbike



ACTIUM: an underwater location marker for divers, devised by the start-up IANIRA and designed by ENSTA Bretagne research engineers.



RAISING STUDENT AWARENESS OF ENTREPRENEURSHIP



Before wanting to create a company, you need to want to become an entrepreneur.

The training at ENSTA Bretagne takes place over 3 years and enables this passion for entrepreneurship to be passed on to our students in a progressive way.

In the first year, all the students receive awareness training

- A conference breaks down all the myths surrounding entrepreneurship. It is delivered by the Technopole Brest Iroise in the presence of entrepreneurs from ENSTA Bretagne's incubator, and discussions rapidly ensue.
- From the 1st semester onwards, the students can also opt to take their first steps in entrepreneurship by choosing startup issues in the "bibliographic writing" project.

In the 2nd year, volunteers can experiment with entrepreneurship

- They can take part in the regional then national Entrepreneuriales competition. 2 teams from ENSTA Bretagne competed in 2019.
- A company creation seminar has been started in partnership with The Corner, and takes place within this private incubator, revealing another environment to the students with its atypical premises. During the 3 days of training, the students have to solve an issue through validating the need and rapidly prototyping a solution (either hardware or software). 35 students took advantage.

Implementation possible in the 3rd year

- The students who specialize in "Business Sciences" can follow the "Entrepreneurship" option and work on their own company creation project. About sixty hours of mentoring from external contributors covers all the aspects of the business plan, so that it can be drawn up and presented to bankers and investors. 9 ENSTA Bretagne student engineers enrolled on this course in 2019, together with 10 PhD students from ENSTA Bretagne and other establishments.
- The students can also continue to develop their companies on their internship, in semester 6, within the framework of their End-of-Studies Project, and aim to join an incubator such as ENSTARTUPS at ENSTA Bretagne.

FOCUS

PATENTED INVENTION

Based on an idea of the startup IANIRA, a patent was registered by ENSTABretagne and granted at the end of 2020.

The associated licensing agreement was signed in January 2021, enabling the markers for divers (ACTIUM system) to be marketed.

This innovative marker allows for extended marking and geolocation of a site underwater, with merits for professional and amateur divers.

A man wearing a grey long-sleeved shirt and a dark face mask is sitting at a desk in a laboratory. He is looking at a computer monitor. In the background, there is a large, light-colored, dome-shaped object, possibly a piece of scientific equipment. The scene is lit with a cool, blueish light. A decorative graphic of many thin, white, wavy lines is overlaid on the image, starting from the left and curving across the bottom. The word "RESEARCH" is written in large, bold, white capital letters at the bottom left.

RESEARCH

RESEARCH

Let us hope that 2020 remains a year like no other, amid the fall-out of the pandemic that has taken such a human toll and given rise to challenging situations all over the world.

At a much more local scale, ENSTA Bretagne's research activities were impacted, particularly during the first-semester lockdown. Experimental activities were put on hold, projects were conducted remotely and the teams found methods for organizing tasks online to keep scientific exchanges going. The importance of maintaining social ties between professors, PhD and post-doctoral students rose to the fore – and had probably not fully been grasped before.

In the end, research activities kept going quite well overall, and the effects of the crisis stemmed mainly from the few weeks or months of delay in the production of findings and study reports. New projects and orders followed in the second semester in particular.

In the short-term then, the consequences of the health crisis have not been too major, but developments in the economic situation over the coming year should be kept a close eye on.

In 2020, preparations were made for the assessment of the school's activities by the High Council for Evaluation of Research and Higher Education (HCERES), particularly its research activities. Besides the research focus

of the school's assessment, the teams devoted time, alongside the other partner institutions, to thinking about and drafting the assessment documents for the research units (UMR IRDL and Lab-STICC), doctoral schools (ED SPIN, College doctoral de Bretagne) and National Master Degrees (DNMs), on an own or joint accreditation basis.

At a time of social distancing, all of these assessment projects were completed on schedule. They are subject to visits by the HCERES committees (virtually, unfortunately), which started at the end of 2020 and are continuing into 2021. Such assessments and audits are important for continuing to accredit the different research facilities in which the school is participating for the 2022-2026 period. And the assessment of ENSTA Bretagne's research strategy is relevant for planning the 2022-2026 objectives and performance contract [COP] which binds the school to its supervisory authority. A growing, significant scientific output, as well as a string of successes, is among the highlights of 2020.

- The IRDL thus joined the CARNOT ARTS Institute, renewed in February 2020, and which is ranked 6th out of 39 in terms of revenues.
- The IRDL, in partnership with Safran Group and Naval Group, was one of the 5 winning candidates to the ANR 2020 call for proposals on industrial chairs: the Self-Heating project, on the study of materials' and structures' fatigue properties, is the first such project to be awarded in the Brittany region, since ANR chairs were set up back in 2011.
- Finally, the school has significantly strengthened its foothold in the field of defense activities, via the launch of 12 new research projects financed by the Defense Innovation Agency [AID]

HUMAN AND SOCIAL SCIENCES

FoAP EA 7529
> page 44

INFORMATION SCIENCES AND TECHNOLOGIES

Lab-STICC
UMR CNRS 6285
> page 36

MECHANICAL SCIENCES

IRDL
UMR CNRS 6027
> page 30

246

RESEARCH STAFF
AND DOCTORAL
STUDENTS



Yann Dautreleau
Scientific Director

124

THESES in progress,
defended and started



12,4 M€

CONTRACTS WORTH
notified in 2020



150


PUBLICATIONS
and papers
at conferences

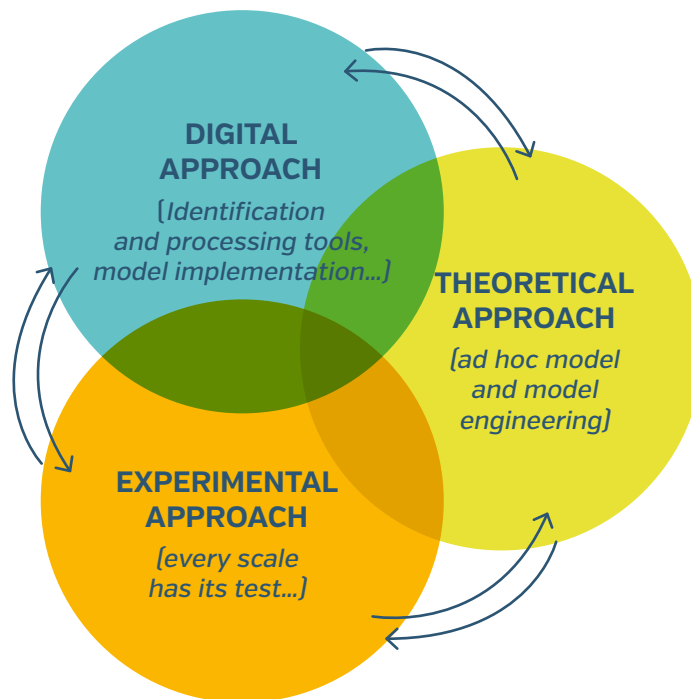
Dupuy de Lôme
research
institute

UMR CNRS 6027
institut Carnot ARTS

IRDL / MECHANICAL SCIENCES

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.
- **300** 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. "



67

PEER-REVIEWED
PUBLICATIONS



53

THESES SUPERVISED



5,95 M€
NOTIFIED,
CONTRACTS

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.

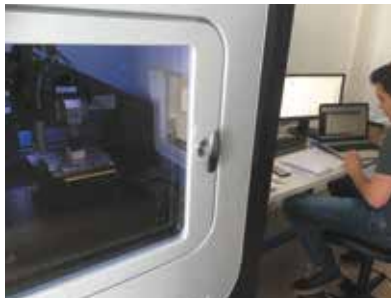
ENSTA Bretagne mainly contributes to clusters 2, 3 and 5 and to a lesser extent, to cluster 1.

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

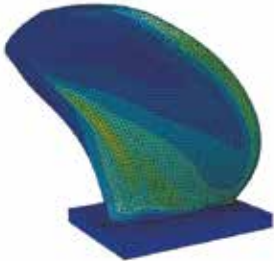
- SEA : offshore, naval construction, MREs.
- TRANSPORT : automobile, aeronautics
- DEFENSE : naval, land.

CONTACT

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Tribolndenter for mechanical testing at the nanometric scale [microstructure of materials]



"Self Heating" ANR Chair with Naval Group and Safran: predict the in-service performance of mechanical systems.

MEMORABLE MOMENTS OF 2020

On January 1, 2020, the IRDL joined the Carnot ARTS Institute

This institute (ARTS stands for Research Activities for Technology and Society) aims to develop cutting-edge research directly linked to the major industrial issues of the future. IC ARTS was one of the first institutes to be awarded the Carnot label by the Ministry of Higher Education and Research back in 2006: this is a guarantee of scientific excellence and quality to encourage partnership-based research to develop.

Inauguration of a 2nd research building dedicated to mechanical sciences

Significant, high-performing experimental facilities have been scaled up for characterization, mechanical loading and metrology. These are wide-ranging and all brought together on the ENSTA Bretagne campus within the MASMECA technology platform.

Thanks to the CPER Regional Development Plan and the DGA, this second building (1,600 sq.m.) and new facilities were delivered at the start of 2020.

- On the ground floor, the rooms are dedicated to mechanical testing on **dynamic and energy phenomena**, with such equipment as a shock tubes, Taylor impact test guns and a pyrotechnics area.
- On the first floor, in addition to the researchers' and PhD students' offices, is a series of specialist technical rooms for studying materials and assemblies at the **microstructure** scale (observation of mechanical and physicochemical properties^o. Examples of equipment: a tribolndenter (for measuring the extent of heterogeneity of a material's mechanical properties, at the micro- and nanometric scale), a scanning electron microscope (for observing a material's physical reaction at atomic scale), a DVS instrument (for very precisely measuring how much water a material absorbs), etc.

Find out more about the experimental facilities in mechanical sciences on page 35 + masmeca.ensta-bretagne.fr

NEW "SELF-HEATING" ANR INDUSTRIAL CHAIR WITH NAVAL GROUP & SAFRAN: predict the in-service performance of air and naval systems

Led by ENSTA Bretagne (Dupuy de Lôme Research Institute), two industrial leaders and including the Institut P, the "Self Heating" industrial chair has been accepted by the National Research Agency (ANR).

- Total budget: €2,050,000, jointly financed by the ANR (50%), Naval Group and Safran (50%).
- Duration: 4 years, from December 1, 2020
- Dedicated team: 8 theses and 4 post-doctorates, supervised by 13 researchers
- Title: characterization, modeling and rapid prediction of materials' high cycle fatigue properties by thermometric measurements
- Objectives and method: measure the heat signature of the fatigue mechanisms of materials for naval and air applications, in order to swiftly predict and determine the high cycle fatigue properties of these materials.

The "self-heating" method entails observation of the temperature curve of a material subject to repeated efforts which lead to its fatigue, under precise experimental conditions, in order to deduce its life span and predict weak points. The rapidity of study and precision of the findings are strengths for industry.

- The digital models thus generated inform design office calculation codes, in order to delay and avoid damage when designing a vessel, submarine or aircraft.
- Safran and Naval Group are committed to extending this scientific approach to all of the materials used in their respective applications and to looking at the parameters acting on the fatigue of their materials (temperature, manufacturing process, type of loading, surface treatments and so on).

A second
1,600 sq.m. building



Durability measurements and testing of bonded assemblies (see focus)

MULTI-MATERIAL ASSEMBLIES

(PTR2)

#

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

21 STAFF
 including 10
 DOCTORAL STUDENTS

17 PUBLICATIONS
 in peer-reviewed
 journals

KEY RESEARCH THEMES

The aims of the IDRL research cluster "Multi-Material Assemblies" are the innovation of assemblies, the characterization of their longterm 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

- Thermal and mechanical characterization of aluminum/ steel multi-material assemblies for automobiles: AM2 project (body-in-white Automobile Multi-materials Multi-processes); financed by BPI, PSA.
- Characterization and modeling of the behavior of thick bonded interfaces and/or in the presence of highly flexible adhesives: COCOA project (ThiCk BOnDED Joint under Complex LOAding); financed by Carnot ARTS Institute, Brittany Region and Département of Finistère.
- Development of technological testing to validate the behavior modeling of impact effects on an adhesive; financed by SAFRAN Composites. Development of a multi-material structural bonded assembly providing ballistic protection; financed by DGA, with 2CA.
- Analytical modeling of the plastic buckling of hulls under pressure; financed by CETIM.
- European "RAMSSES" project: study of composite/steel joints (see page 35)

FOCUS

DURABILITY OF BONDED MULTI-MATERIAL STRUCTURES TO CAPTURE MARINE RENEWABLE ENERGIES

This ANR France Energies Marines INDUSCOL project (2016-2020), brings together ENSTA Bretagne, UBS, the University of Nantes and Naval Group. David Thevenet, scientific and technical lead on the project: "Offshore durability of MRE structures over periods of up to 15 years remains

a major challenge. These structures are manufactured using combinations of materials, often assembled by structural adhesive. The study bore on the long-term performance of the adhesive line in a bid to foster the introduction of innovative multi-material structures.

Drawing on a wide range of experimental findings and instrumentation of the adhesive line by different sensors, digital models have been developed to predict the change in mechanical resistance of the bonded assembly over time.

1 THESIS DEFENDED IN 2020

- **Vincent DUMONT** (CIFRE Safran Reosc): "Durability of glass-metal adhesives for space optics in thermal environments" This thesis applies to the ELT (extremely large telescope), a revolutionary giant telescope which will be installed in northern Chile, at an altitude of 3,060 m.

2 NEW THESES

- **Thomas Fkyerat** (Brittany region and Brest métropole grants): "Optimization, characterization and modeling of metal thermoplastic composite hybrid assemblies"
- **Andreea Gabriela Tintatu** (contract DGA, Thales): "Simplified modeling of bond assemblies for the mechanical characterization of adhesives and substrate-bond interfaces and analysis of their aging."

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RESEARCH

STRUCTURE, FLUIDS & INTERACTIONS

(PTR3)



© SOLIDSAIL

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

HYDRODYNAMIC

- STADINAV: Probabilistic analysis of the non-linear rolling motion of vessels subject to irregular wave swell [Financed by AID, in conjunction with Ecole navale]. This project sets out to develop new methods for predicting the risk of vessels capsizing.
- DIMPACT: Sizing of floating wind turbines with account taken of wave breaking and impacts [Financed by ANR / France Energies Marines]
- OPTIFOIL: Parametric optimization of foils; application to the Olympic sail [Financed by the Carnot ARTS and MERS Institutes, with Ecole navale and IFREMER]

PYROTECHNICS

- TRIBAL: Transparent composite ballistic protection [Financed by ANR ASTRID]
- Scientific cooperation with Nobel Sport, Eurenco, Livbag, etc.

3 THESES DEFENDED IN 2020

- **Pierre LEGRAND** [Cifre NECS]: "Setup of a methodology for predicting the effects of explosions on civil engineering infrastructure".
- **Yumna QURESHI** (with HEC, Campus France): "Development of a sensitive, robust system of sensors to monitor the deformation of composite structures in real time." [PTR 1 composites].
- **Corado NINGRE** (with Grenoble-Alpes Univ.): "Modeling of multiaxial cyclic elastoplastic behavior by a multisurface approach in the space of deformations".

4 NEW THESES

- **Mathieu GORON** [ONERA, Ifremer]: "Oblique hydrodynamic impacts in rough seas".
- **Antoine POIROT** [Estaca]: "Development and modeling of functional structures based on the implementation of piezoresistive syntactic foams. Application to the monitoring of structures subject to shocks".
- **Agathe DE LA HOUGUE** [IFREMER/Ecole navale]: "Parametric optimization of foils Application to the Olympic sail".
- **Marion BRATEAU** [CIFRE CTAI]: "Modeling of multiphysical coupling during an interior ballistic cycle in next-generation ammunition".

FOCUS

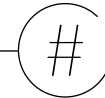
SOLID SAIL 2.0, 100% COMPOSITE RIGID SAIL

The traction of the sailing cruise vessel "SILENSEAS" (Chantiers de l'Atlantique) will be ensured by innovative rigid sails. Together with the future manu-

facturers, the researchers have modeled their design: they have designed computational chain factoring in the expected traction performances and wind

behavior and tested it on a 1:5 scale prototype. The "Jibsea" program is poised to take over in 2021.

www.ensta-bretagne.fr/en/solid-sail-20-100-composite-rigid-sail

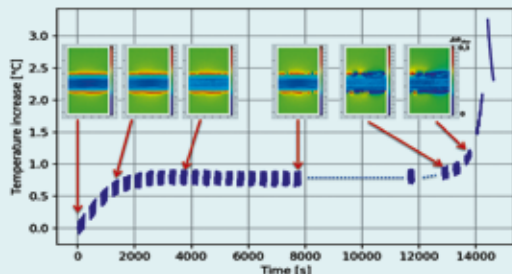


- # modeling # digital simulation
- # experimental mechanics
- # materials and structures
- # dynamics # shocks
- # impacts # structure-fluid interactions

47 STAFF
including 20
DOCTORAL STUDENTS

35 PUBLICATIONS
in peer-reviewed
journals

+ 4 DOCTORAL
STUDENTS belonging
to PTR1 Composites



Temperature measurement during fatigue tests on welded assemblies.



fatigue # aging # fatigue resistance # modeling # testing

28 STAFF
 including 19
 DOCTORAL STUDENTS

15 PUBLICATIONS
 in peer-reviewed
 journals

FOCUS

TAKING THE TEMPERATURE OF VESSELS TO PREDICT THEIR LIFE SPAN

For 15 years, with fewer samples, less time but more precision, self-heating testing has been advancing knowledge of the in-service performance of materials and assemblies for naval, inland and air applications.

Loïc Carteron, PhD student: "We analyze the temperature curves of parts to identify the weak points and avoid damage from the design stage.

These huge, complex steel structures are primarily assembled by welding. At sea, the welds are very often the weak point where cracks begin.

The challenge for engineers involves designing the hulls of vessels by guaranteeing the longest life span possible.

We supply these prediction models. For that, lab testing reproduces the stress that the parts endure at sea: this stress is re-

latively weak, but repeated time and again, which generates a fatigue characterized by a rise in temperature.

Such self-heating measurements are then analyzed, setting the stage for predictions of the in-service life span."

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.

BEHAVIOR AND DURABILITY OF HETEROGENEOUS MATERIALS (PTR5)

5 THESES DEFENDED IN 2020

- **Cédric BAIN** [CIFRE Inorope]: "Understanding and modeling of the contact mechanisms of cables in Ultra High Molecular Weight Polyethylene for naval applications"
- **Loïc CARTERON** [CIFRE Naval Group]: "Contribution of temperature field measurements under cyclic loading to characterize and model the fatigue properties of welded assemblies"
- **Yoan CHEVILLOTE** [with France Energies Marines and IFREMER]: "Characterization of the long-term mechanical behavior and durability of polyamide mooring cables for floating wind turbines [Marine Renewable Energies]"
- **Prashant SANTHARAM** [CIFRE Vibraacoustic]: "Thermomechanical investigation for the fatigue sizing of short fiber reinforced thermoplastic parts for automotive applications"
- **Vincent ROUE** [CIFRE Safran Aircraft Engines]: "Rapid determination of the high-cycle fatigue properties by self-heating measurements under cyclic loading: application to metal alloys for aeronautical turbojet engines."

6 NEW THESES

- **Vanessa KWIATKOWSKI** [CIFRE Safran Landing Systems, "self-heating" chair]: "Fatigue in short-fiber thermoplastic composites for aeronautical applications subject to complex pressure loading"
- **Ewann GAUTIER** [AMERICO contract]: "A simplified approach for complex cyclic loading fatigue life calculation in a confined plastic zone"
- **Corentin GUELLEC** [CIFRE Naval Group]: "The fatigue life of high-cycle naval application drive shafts"
- **Enora BELLEC** [CIFRE Groupe PSA, OpenLab "Computational Mechanics"]: "Load spectrums for the mechanical sizing of an automotive vehicle"
- **Antoine LE PALABE** [region grant, UBS]: "Residual stress and fatigue of composites - Application to competitive sailing"
- **Laure CIVIER** [FEM grant]: "Monitoring of polyamide mooring lines for offshore wind turbines."

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RESEARCH

GUSTAVE ZÉDÉ JOINT LABORATORY

(NAVAL GROUP, ENSTA BRETAGNE)

EUROPEAN "RAMSSES" PROJECT FOR FUTURE SHIP DESIGN

"RAMSSES" is aimed at enhancing the life span of naval structures while reducing their environmental footprint. This involves incorporating lightweight materials for enhancing the mechanical performances of ships.

The teams are conducting experimental research and modeling on issues associated with the resistance and durability of materials used in the military naval industry.

- 36 partners across 12 countries
- €13.5m total budget over 4 years
- 13 research strands, 2 of which are led by ENSTA Bretagne and Naval Group

COMPOSITE USE FOR SUPERSTRUCTURES

Also involving the Bureau Veritas, the end goal of this subject is the use of lightweight parts located above the ship's deck, by replacing the steel walls with composite walls. New material use brings into the equation **the mechanical resistance and durability of composite/steel mixed assemblies.**

T-shaped test specimens representing a deck/superstructure joint, comprising a steel base plate and composite panel, were produced by Naval Group. Various steel/composite joints could thus be tested at ENSTA Bretagne: riveting, bonding or mixed assembly.

▶ Vidéo : youtu.be/EjHatFx0BW4

HOLLOW PROPELLER OBTAINED FROM METAL ADDITIVE MANUFACTURING

Additive manufacturing could replace current processes (casting) for producing marine propellers. A hollow blade obtained from metal additive manufacturing, produced by Naval Group and Centrale Nantes, has been tested at ENSTA Bretagne.

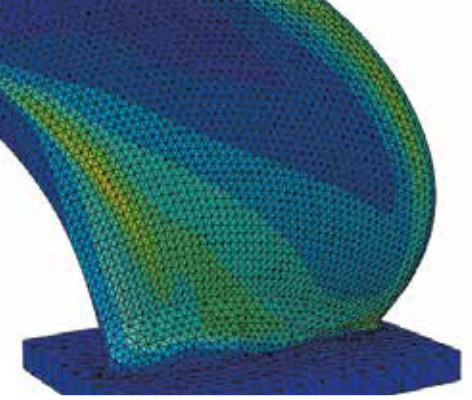
The 3D metal printing process paves the way to innovative geometric forms but also raises new mechanical questions. The complex gross area reveals the layers of material deposited, and the thermal background of these parts also brings new properties to the fore. New models and testing are therefore necessary to take these characteristics into account when sizing the propeller.

▶ Vidéo : youtu.be/5FHejypT1SA

MODELING AND TESTING

- These structures were modeled with account taken of the complexity of the materials and repetitive cyclic loading they will undergo.
- Tests were then performed on the multi-axial platform*, by reproducing the actual loading. Composite panel core measurements and surface observations of the blade revealed the areas and conditions in which the first defects appear, confirming the relevance of the digital prediction models with which manufacturers will be equipped.

* The multi-axial platform is unique in Europe. It is one of the most impressive experimental facilities making up the outstanding technology platform MASMECA located at ENSTA Bretagne. Find out more at: masmeca.ensta-bretagne.fr



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



"GUSTAVE ZEDE" JOINT LAB


- Set up in 2015 at ENSTA Bretagne, this lab relies on the Dupuy de Lôme Research Institute (CNRS joint research institute).
- This joint R&D initiative enables the development of innovative tools to assist in the sizing of naval structures subject to extreme loading.
- Modeling and experimental research aim to predict fatigue resistance.
- Different research programs are conducted, such as FRAPAN, INCOLA, AMERICO and RAMSSES.

www.ensta-bretagne.fr/en/gustave-zede-joint-laboratory

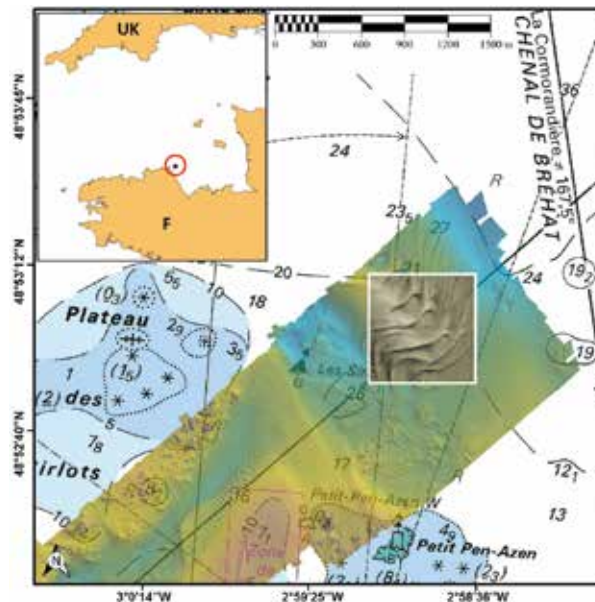
Knowledge, Information
and Communication
Science and Technology
Laboratory
UMR CNRS 6285

LABORATOIRE LAB-STICC

PROFILE

- **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.
- **577** staff, including 206 doctoral students. Approximately
- **500** publications /year.
-  www.labsticc.fr

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



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:

The lab is organized into several inter-institution teams working on different themes. Cross-cutting programs delve into such highly inter-disciplinary themes concerning society as:

- aids for dependent people.
- cybersecurity and cyberdefense.
- the Sea and the Information & Communication Science & Technology sphere.
- the new methods of information processing and representation for artificial intelligence.
- drone systems.



75
PUBLICATIONS



54
SUPERVISED THESES



€M 6,225
NOTIFIED CONTRACTS



Left to right: Karl Sammut (Flinders University) and Benoît Clément (ENSTA Bretagne & Flinders University)

MEMORABLE MOMENTS OF 2020 CONSTRUCTIVE COLLABORATION WITH AUSTRALIA

Benoît Clément, robotics professor at ENSTA Bretagne, has also become an Associate Professor of Flinders University, after an 8-month research trip to this Australian university.

Benoît, how did this mobility come about?

"Everything began with Australian partners visiting ENSTA Bretagne, especially Tony Kiriakou and Karl Sammut from Flinders University. Karl and I have followed very similar scientific pathways and we found we had research subjects to develop in common straightaway.

At the same time, I led the construction of a joint laboratory between ENSTA Bretagne, Naval Group and Flinders University, bearing on autonomous vessels. With the all-round enthusiasm of my family, all we had to do was put the mobility actually into practice!

The DGA, Region of Brittany and ENSTA Bretagne were a great help in enabling this trip to go ahead smoothly. At the Australian end, Flinders University made first-rate working tools available to me. Tony and Karl's support was also invaluable.

What activities were you involved in at Flinders university?

"Besides the very different ways of working that I was able to really get to grips with and which I will be able to share with our students, my activity was geared towards underwater robotics research. This was conducted jointly with students from Flinders who came to France, at ENSTA Bretagne (Lab-STICC), on Nicolas Baudin scholarships. When they got back to Australia, we were able to continue the research on simulation tools for controlling autonomous marine systems."

What will you take away from this experience?

"It wasn't easy to talk my family into leaving Australia!... Scientifically, constructive exchanges are continuing despite the distance. By organizing things differently and adopting a different mindset and way of thinking, ideas and our perception of the world can progress. Dedicated entirely to **my research**, this trip was an opportunity to make **progress on the links between automation, machine learning (AI) and optimization**.

New research subjects are set to emerge with Flinders University, in GNC (Guidance, Navigation and Control), object classification and cybersecurity for example."

SCIENTIFIC TEAMS TO WHICH ENSTA BRETAGNE CONTRIBUTES

Les équipes ENSTA Bretagne couvrent les 3 pôles scientifiques du Lab-STICC et contribuent à 6 des 11 équipes scientifiques et à 5 des 6 domaines trans-verses.

- TOMS:** Statistical Methods, Observations and Processing ["MATRIX" team from 2021].
- PRASYS:** PRASYS: Perception, Robotics, Autonomous SYStems ["AI" department and "MATRIX" team from 2021].
- COM:** COM: Digital communication ["SI3" team from 2021].
- MOCS:** MOCS: Systems, Circuits, Tools and Methods ["SHARP" department from 2021].
- PIM:** PIM: Multi-Scale Interactions and Propagation.

From 2021, the Lab-STICC is being reorganized into **6 new departments, including 17 new teams**.



PROJET "MÉDITERRANÉE"

Le 29 sept. 2020, le directeur de l'ENSTA Bretagne a signé une convention de partenariat avec la Fondation Van Allen (Université de Montpellier) en présence d'Annick Girardin, ministre de la Mer. Les travaux

de recherche portent sur l'amélioration des **modèles météorologiques de prévision d'épisodes cévenols** (fortes précipitations).

Pierre Bossier, enseignant-chercheur pilote du projet: « Une thèse a débuté en décembre 2020. Elle vise à améliorer les méthodes d'analyse des signaux GNSS (GPS, Galileo, Glonass) mesurés par des antennes embarquées en mer ».

Creation of the Group of Scientific Interest CORMORANT* by Thales and academic partners of West Brittany.

December 9, 2020

This is the 2nd GIS Thales has set up in France. This unique regional mechanism, with a national and international outreach, encourages close cooperation between all of the research stakeholders in West Brittany with a view to driving forward innovation across 3 areas:

- smart processing and sensors
- human-machine interfaces and human factors
- autonomy of maritime systems Researchers from the CNRS, ENSTA Bretagne, IMT Atlantique, Brest National School of Engineering (ENIB), UBO, UBS (which form the Lab-Sticc) alongside those from the Naval Academy, ISEN and Thales form a world-ranking center of expertise for marine drone or electronic warfare programs. The international co-operative ventures involved are firmly geared towards Asia and Australia.

"SENI" joint laboratory with Naval Group on Intelligent Naval Embedded Systems.

The work in progress concerns systems for acquiring information on the environment and vessel function, and implementing decision and action processes on board.

The Naval Systems Cyberdefense

Chair With the support of the French Navy, the Region of Brittany and Cyber Center of Excellence, the Chair aims to protect digital equipment and detect cyberattacks in maritime systems. 10 theses are in progress, led by the 5 partners (Ecole navale, IMT Atlantique, Naval Group, Thales and ENSTA Bretagne).

* CORMORANT "Collaboration for Research regarding Maritime technologies, for Observation, security, and surveillance with Thales"

PROCESSING, OBSERVATION AND STATISTICAL METHODS

SAR image of the Strait of Messina, captured on September 8, 1992 by the ERS-1 satellite [ESA]



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

10 ARTICLES
 articles in international
 conference proceedings

17 STAFF including 10
 DOCTORAL STUDENTS

10 PUBLICATIONS
 in peer-reviewed
 journals

APPLICATIONS

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

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

OCEAN FLUCTUATIONS

The ocean is the scene of all sorts of random physical phenomena of unknown origin, which can alter the way in which soundwaves are propagated there and thwart conventional approaches for locating acoustic sources. ENSTA Bretagne and DGA Naval Techniques branch are developing new robust processing of such fluctuations, requiring steps

ranging from the description of oceanographic phenomena to the proficient use of probabilistic algorithmic tools, via modeling of sound propagation in a random environment. The French Naval Hydrographic and Oceanographic Service (Shom) and Thales are joining in this research by jointly supervising a thesis from January 2021.

RESEARCH PROGRAMS

> IN SIGNAL PROCESSING AND ARTIFICIAL INTELLIGENCE

- Deep learning and marine environmental observation: detection and recognition of multiple objects on variable beds by deep learning (with IRISA, UBO, UMR AMURE, MBDA); physics-guided probabilistic deep learning for underwater acoustics (financed by DGA/AID).
- Drones and signal processing: digital analysis of drone data (ERDF).
- Acoustic data processing to characterize the marine environment; study of physical quantities relevant for machine learning in underwater acoustics and fluctuating environments (financed by DGA/AID).

> IN BIOACOUSTICS & ENVIRONMENTAL STUDIES

- Contract with the Biodiversity Agency for passive acoustic surveillance of cetaceans in the second volume of the Marine Strategy Framework Directive (MSFD) established by members of the European Union.
- OSMOSE (open science meets ocean sounds explorer): collaborative underwater acoustics project for ocean observation (with IMT Atlantique, IUEM and Woods Hole Oceanographic Institution).

4 THESES DEFENDED IN 2020

- **Guillaume BEAUMONT** [DGA contract]: "Correction of the effects of decoherence induced by fluctuations of the propagation environment".
- **Maëlle TORTEROTOT** [Region grant]: "Processing and analysis of bioacoustic signals in the southern Indian Ocean".
- **Paul NGUYEN HONG DUC** Hong Duc [DGA grant]: "Development of artificial intelligence methods for marine mammal detection and classification of underwater sounds in a weak supervision (but) Big Data-Expert context".
- **Antoine D'ACREMONT** [CIFRE MBDA]: "Recognition and identification of infrared imaging targets by deep learning".

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RESEARCH

PERCEPTION, ROBOTICS AND AUTONOMOUS SYSTEM



Drones d'observation marin et sous-marin pour la cartographie autonome du lac de Guerlédan.

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

KNOWLEDGE AND DESCRIPTION OF THE MARINE ENVIRONMENT

- Projects conducted with the Shom: improve knowledge of surface current measurements by HF radar; bathymetric modeling by radiative inversion of multispectral images; study and precise navigation simulation of AUVs in hydrography (Navidro).
- DGA projects: Rapid project on autonomous navigation by visual and acoustic recognition for relocation [NARVAL]; conversion of existing underwater drones into connected objects able to conduct large-scale observation and evaluation missions of the underwater environment [PROTEUS].

OCEAN AND ATMOSPHERE

- Project financed by the CNRS National Institute for Earth Sciences and Astronomy (INSU) as part of the Ocean-Atmosphere program and "Fluid envelopes and the environment" (LEFE) study: the team has initiated the "GEMMOC" project on Offshore Embedded GNSS for Meteorology and Climatology.

1 THESIS DEFENDED IN 2020

- **Charles COQUET** (CIFRE Thales) : "Multi-agent search of a source by measurement of an associated scalar quantity".

2 NEW THESES

- **Nathan FOURNIOL** (region and Thales): "Communication with autonomous naval intermediate relays (CORINA)".
- **Mohamed Ali GHANNAMI** (jointly supervised by Laval Univ. in Quebec, Brittany region/IFQM grant): "Statistical inference of water column height by radiometric and geometric analysis of spectral images".

FOCUS

UNIQUE EXPERTISE IN UNDERWATER ROBOTICS

Since September 2020, Simon Rohou, professor of autonomous robotics, has been leading the "Marine and underwater robotics" strand of the Robotics Research Group, set up by the CNRS: "The aim is to develop communication between stakeholders in the field and to stimulate collaborative working within the French community. There is a wide variety of themes, such as exploration of underground lakes, developing snake-shaped robots inspired from life, searching for wrecks or collaboration of underwater gliders and mapping of the seafloor."

ENSTA Bretagne is studying the challenges of autonomous, mobile and underwater robotics: localization, monitoring and coordination of robots are particularly complex tasks to take up in the marine environment (little or no visibility, no GPS for getting into position, etc.). The team designs these robots and develops their embedded intelligence thanks to the multidisciplinary skills that can all be found on-campus: physics of the marine environment, sensors, mobile platform design, programming, localization and control algorithms.



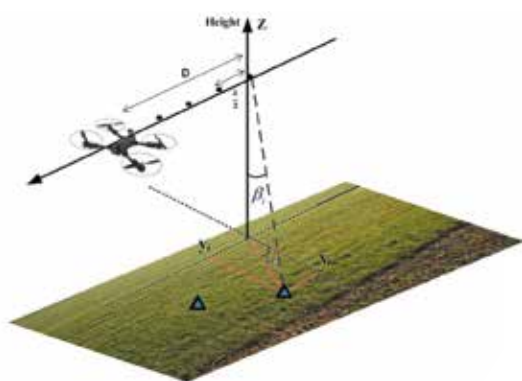
mobile robotics
autonomous system # localization
perception # control

29 STAFF including
14 DOCTORAL
STUDENTS

10 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

20 STAFF including
12 DOCTORAL
STUDENTS

9 PUBLICATIONS
in peer-reviewed
journals
+ 1 conference paper

APPLICATIONS

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

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

AIR-GROUND INTERACTIONS AND LIAISONS FOR AIRCRAFT AT LOW ALTITUDE

› AID project

The aim is to model the electromagnetic interactions between a terminal on the ground and an aircraft (plane or drone) flying at low altitude, with account taken of the terrain and more generally the ground irregularities for a variety of settings (mountains, wooded areas, urban environments and so on). Such modeling should enable an assessment of the air-ground communication quality on aeronautical systems in landing or takeoff phases, or during long-distance missions.

4 THESES DEFENDED IN 2020

- **Mahmoud Al Masri** [grant from Lebanon with the Lebanese University]: "Gaming theory for tactical military communications".
- **Jean-Marie Kadjo** [grant from Cote d'Ivoire]: "Spectral and Temporal Analysis of Digital Communications Signals and Cognitive Radio Applications".
- **Michel Ghattas Akkad** [grant from Lebanon, Balamand University]: "Optimization and implementation of beam-forming algorithms on embedded systems".
- **Ms Moawad Azza** [AAMSET, Egypt]: "Reinforced approaches of spectral detection in the cognitive radio context: Identification of reliable spectral opportunities".

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 hopital des armees 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

- **Aurélien OLIVIER** [Brest Regional University Hospital, ENSTA Bretagne]: "Deep learning and methods for characterization of deep vein thrombosis by ultrasound and elastography"
- **David ABEZA** [ENSTA Bretagne, Ecole navale]: "Strengthening the security of a wireless network's physical layer by advanced signal processing"

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RESEARCH

METHODS, TOOLS, CIRCUITS AND SYSTEMS



TGCC Joliot-Curie supercomputer established at CEA

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 team is studying embedded systems from the point of view of their security, operating safety, energy consumption and performances, at multiple levels:

- software: federation of heterogeneous models, formal verification techniques;
- hardware: securing of the compilation flow for circuits, virtualization of reconfigurable architectures to design durable and secure systems on chip (SoC), variability management;
- cross-cutting: data management, application storage, hardware support to guarantee quality of service.

RESEARCH PROGRAMS

- Execution and formal verification of models of systems developed using the NATO Architecture Framework (RAPID "VeriMoB" with PragmaDEV and AID).
- Securing architectures and operating safety: "JoinSafeCyber" (with ENSTA Paris and AID); test system and methodology for connected vehicles ("KER-SEVECO", with KEREVAL, Mobility Tech Green and Brittany Region); securing Overlay architectures for digital circuits to remain operational over long periods of time (with AID).
- System and software security by contract (with AID).
- Big data management and storage: "DataMeSS" (with the CEA) on heterogeneous storage infrastructures; "IRT SUPRA" (with IRT b-com) on the effective use of heterogeneous computational resources in the "Cloud."

THESIS DEFENDED IN 2020

- **Valentin BESNARD** (contract CIFRE Davidson Consulting, with ESEO): "Unifying analysis of embedded execution with the help of a controllable model interpreter". Main findings: mathematical formalization of the software framework, production of a "bare-metal" UML model interpreter and assessment across several scenarios (automotive, rail, aeronautics, robotics).

4 NEW THESES

- **Quentin DUCASSE** (Brest, Cyber Center of Excellence): "Software-hardware deployment of secure virtual machines: Heterogeneous Risc-V Manycore Platform for the IoT".
- **Matthias PASQUIER** (CIFRE ERTOSGENER, with ESEO): "Express consideration of an embedded operating system in a cybersecurity certification process".
- **Luis THOMAS** (with the CEA): "Optimization of data placement in HPC storage systems via machine learning mechanisms".
- **Hiba HNAINI** (with AID): "Toward a unifying framework for the specification, formalization and analysis of secure software and hardware architectures" (IFS2ALP project).

FOCUS

DATA MANAGEMENT AND STORAGE

A stack of CDs covering the equivalent distance of 5 journeys from the Earth to the moon and back... that's how much data is expected to be stored worldwide by 2025! The priority is to ensure highly effective, safe and energy-efficient storage: defining placement strategies ("DataMess" strategy), supervision mechanisms ("IDIOM" project), etc.

CYBER MARITIME

The team's expertise in terms of IT and electronics is wide-ranging to tackle the field of cybersecurity. They benefit from an extensive range of cutting-edge facilities, acquired thanks to the CPER "Cyber-SSI" project. They particularly take up the challenges of France Cyber Maritime, a French sector of excellence created at the end of 2020, to contribute to a safer digital maritime world.



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

20 STAFF including 11 DOCTORAL STUDENTS

19 ARTICLES in publications and international conference proceedings

MULTI-SCALE INTERACTIONS AND PROPAGATION

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

CHARACTERIZING MARINE WINDS USING SATELLITE IMAGING

CEPAMOCS project: Characterization and retrieval of heterogeneous sea surface parameters observed by different satellite sensors.

Financed by: AID, DGA, EGS. High-resolution estimations of wind speed and direction from synthetic-aperture radar (SAR) imaging are key to characterizing a marine environment in offshore or coastal areas. In this project, several methods were considered. What's more, regarding wind direction estimations, a method to improve the spectral method with the Radon Transform is proposed. One of

the objectives is to determine which method yields the best results, particularly when the resolution grid is at a smaller scale. The precision, accuracy and uncertainty of methods are compared through an evaluation and simulation study with Radar SAT2 data (in the coastal area) and another with Sentinel-1 data (in the offshore area).

RESEARCH PROGRAMS

- **e-PANEMA** (cf. photos): e-positioning and navigation support in the maritime environment (financed by Ademe ; with SAFRAN,Diades Marine, ENSM).
- SLERECIM : The addition of GBS and GBL to the estimation of complex target reflectivity at sea (financed by DGA, AID, OAR).
- 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).
- CASSIOWPE: Characterization of atmosphere-sea surface interactions for the roll-out of offshore wind turbines in the Gulf of Lion (2020 – 2023, France Energie Marine, 15 national and international partners).

2 THESES SUPPORTED IN 2020

- **Ngoc TAN TRUONG** [[grant e-PANEMA, ADEME, with SAFRAN, DIADES Marine and ENSM]: "*Multi-source hybridization for improvement of detection, tracking, location and positioning functions in difficult environments*".
- **Antoine FOUCAULT** [CIFRE Thales]: "*Detection of LPI radars*"

1 NEW THESIS

- **Aurélie PANETIER** [region, ENSTA Bretagne, Van Allen Foundation]: "*Embedded GNSS at sea for metrology and climatology: development of methods for analyzing GNSS data acquired by antennas embedded out at sea for improvement of the trajectory and characterization of atmospheric water vapor (Mediterranean project)*"

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).

Measurement campaign for the e-PANEMA project



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

3 STAFF including
5 DOCTORAL
STUDENTS

115 PUBLICATIONS
in peer-reviewed journals
and international
conference proceedings

+ 2 DOCTORAL
STUDENTS
in the "Multiphysical
devices and interfaces"
research team

TEST FACILITIES IN ISTC AND MECHANICAL SCIENCES

Assessment of the 2015-2020 CPER

The State-Region Plan Contract (CPER), which has now ended, has enabled a significant increase in research facilities in the strategic projects selected.

« CYBER SSI »

Cybersecurity of software and physical systems.

Cybersecurity research at ENSTA Bretagne primarily focuses on the analog chain (antennas and filters for secure communication), computational devices (electronic chips), and development of software tools (secure system design, synthesis of applications guaranteeing respect for intellectual property, formal validation method analysis). Total amount: €2m

Main acquisitions:

- Computer, virtualization server
- Hardware emulator, hardware accelerators
- SCADA (supervisory control and data acquisition) platform
- Radiofrequency bench
- Drones

« SMD-MAR »

Marine environment observation using autonomous robots.

This equipment enables the design and testing of groups of autonomous drones, across multiple environments (marine, underwater and air) for the exploration and surveillance of the marine environment, with precision and in a repetitive manner. The scientific challenges encompass propulsion, navigation, acquisition and processing of information, sensors, embedded intelligence and autonomy among others. Total amount: €865k

Main acquisitions:

- Acoustic sensors
- CNC machine for rapid prototyping
- Multi-environment robotic platforms and drones
- Instrumentation & Control mobile station

« SOPHIE »

Microwave acquisition systems to characterize the maritime environment under different conditions

Total amount: €46k

Main acquisitions:

- Equipment for production of the acquisition system (up/down converter modules and broadband antennas).

« I-ROMI »

Design of new, passive acoustic observatories for monitoring and analyzing ambient noise (geological phenomena, human activities and wildlife).

Total amount: €690k

Main acquisitions:

- Multi-channel data acquisition units for locating marine mammals and vessels
- Single-channel data acquisition units for long-term, continuous noise monitoring
- Click detectors for monitoring the acoustic location of small cetaceans.
- Portable hydrophones
- Computational server

"ECO-SYS-MER"

The aim is to strengthen the reliability of marine mechanical systems, from the scale of the material to that of the system.

Total amount: €2.075m

Main acquisitions:

- Electromechanical compression/traction machine
- Electrodynamic compression/traction fatigue machine
- Scanning electron microscope
- X-ray diffractometer (XRD)
- Micro-nano-tribo-Indenter
- Cameras (one infrared, two high-speed)
- Physicochemical analytical equipment (DSC, DVS), etc.

5 strategic research projects represent €5.6m worth of new equipment from 2015 to 2020 (financed by the CPER1), i.e. €460k in investments for 2020.

FOCUS

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 ...



Professional training
and apprenticeships
training
UE 7529

FoAP RESEARCH


UNIT / HUMAN AND SOCIAL SCIENCES

109 MEMBERS,
including 45
DOCTORAL STUDENTS,
47 permanent members
and 17 associate researchers.

including **10**
RESEARCHERS AND
16 DOCTORAL STUDENTS
in the engineer training and
professionalization (FPI team)

19 ARTICLES
in publications and
scientific chapter

PROFILE

- Created on 1 January 2019, FoAP replaced the CRF [Centre de Recherche sur la Formation
- Training Research Center] It brings together the training and education science teams from 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.
-  foap.cnam.fr



FOAP SCIENTIFIC PROJECT

Multi-supervisory and inter-regional, FoAP is the only laboratory to be dedicated to adult training and vocational training in France, and thus oversees a network of researchers on training questions in the broad sense, including initial vocational training, higher education, lifelong learning, active apprenticeships and career paths.

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. Initial vocational training and continuing professional development have long been a focus of activity for the Ministry for the Armed Forces and Ministry for Food and Farming. The teams at the three establishments share the same vocational training culture, at a high level of expertise, across a wide variety of fields such as health, engineering, agronomy and social work.

Three key themes:

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

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MEMORABLE MOMENTS OF 2020

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).

The mobility programs and surveys planned in 2020 were disrupted by the successive lockdowns, but 2 theses were defended. The project will be finalized in 2021.

1 THESIS DEFENDED IN 2020

• **Imane Zergout** (RIIME project, jointly supervised with Hassan II University in Casablanca) "training of engineers in innovation".

She outlines a continual improvement approach for improving future Moroc-

can engineers' training in innovation. The socioeconomic scene in Morocco is thriving, with major development projects open to the whole of Africa and inspiring debates across higher education. The engineering schools are looking to adapt to be able to take up the challenges of such a development and are seeking to train innovative-minded engineers. What is distinctive about Imane Zergout's thesis is its multidisciplinary.

She has harnessed industrial engineering, innovation engineering and the education sciences. This has been possible thanks to the joint supervision set up: the thesis was supervised by Souad Ajana and Soumia Bakkali, both mechanical engineering professors at ENSEM Casablanca [Engineering Training Research Team] as well as by Catherine Adam, a researcher in the education sciences at ENSTA Bretagne (FoAP lab).

Projet A-STEP2030

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. In 2020, two European studies were undertaken: a quantitative survey asking

engineering students at European level about their perception of the training delivered in their institutions; and a qualitative study among faculty at 12 European engineering schools about the teaching they give to train their students in sustainable development. The findings were shared during three European workshops, a symposium in the context of the SEFI 2020 conference, four papers and five pan-European online webinars. It became clear that there is a need to redesign programs so as to train future engineers who are empowered with all the skills required to resolve the challenges of sustainable development. The A-STEP2030 project is seeking to come up with innovative teaching methods that are closely aligned with these objectives.

www.astep2030.eu/en

« L codent L créent » project

« 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.

www.ensta-bretagne.fr/en/l-codent-l-creent-project

FPI TEAM

SCIENTIFIC PROJECT

Consider the engineering profession and its training. The team is looking at the relationship between the social and the technical sides, from the point of view of identities, knowledge, organizations and learning. It is taking on board the sociocultural dynamics from the micro level [e.g.: the individual before the technical system] to the macro level [e.g.: global development in engineering training systems]. **Training responsible innovators, ready for action in favor of sustainable development** The various research projects in progress bear on engineers' training in responsible innovation. The team is working on developing a sociotechnical approach to problems, combining the technical, economic, legal, human, social, environmental, political and ethical considerations...

CAMPUS

Key spatial developments of 2020 include:

- the interior layouts and installation of new experimental facilities at the research center
- repair work on a damaged research space
- investments for distance and blended learning
- renovation of a square and the stadium
- studies have begun on construction of a dedicated building for training, research and experimentation in robotics.

BUDGET : M€ 24,8

[CASH CREDITS 2019]

RESSOURCES	EXPENSES
Subsidy from the Ministry for Armed Forces ▼ M€ 14,9	Staff ▼ 16,7 M€
Other resources [research, training ...] ▼ M€ 9,6	Operating costs ▼ 5,8 M€
Equity ▼ 0,3 M€	Investments ▼ 2,3 M€

NUMBERS

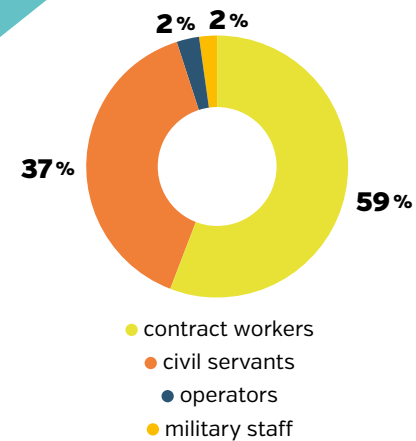
[NOT COUNTING DOCTORAL STUDENTS]

A multi-disciplinary team of **244** people

- > **75** lecturers [25 of which accredited doctoral supervisors]
- > **25** teachers
- > **20** technicians
- > **27** research engineers
- > **20** post-doctoral researchers
- > **77** support and supervisory staff [including 2 apprentices]
- > and **320** supply teachers

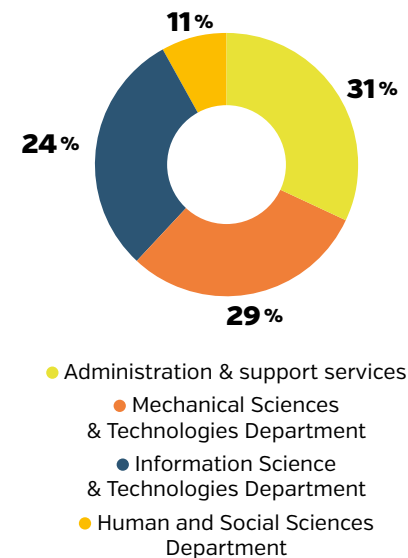
STATUTS

STAFF



MISSIONS

STAFF



1/3
of the application projects
aim to reduce the
environmental footprint

ENSTA Bretagne has
created 4 new "cordées
de la réussite" mentoring
schemes with high schools
and secondary schools
in finistère.

ENSTA Bretagne is
contributing to the
discussions by sustainable
development and social
responsibility leaders of
the association of grandes
écoles (CGE).

In september 2020,
it responded to the grand
baromètre survey of the
student movement "for an
ecological awakening"
(national survey on good
sustainable development
and social responsibility
practices in higher
education).

New ambitions in connection
with these themes are in the
pipeline (COP 2022-2026).

A "workplace equality"
correspondent has been
appointed, in addition
to the network against
harassment and
discrimination

SUSTAINABLE DEVELOPMENT & SOCIAL RESPONSIBILITY



SOCIAL RESPONSIBILITY TRACK RECORD

ENSTA Bretagne defends the values of openness, tolerance, diversity and is pro-active in reducing inequalities and ensuring the well-being of everyone at work.

- Preventing and combating harassment and all forms of discrimination [« [stopdiscr](#) » network].
- Encouraging and endorsing citizenship and solidarity [commitments](#) on the part of the students.
- Changing attitudes to [disability](#) and informing future engineers of how to receive people with disabilities in the professional environment
- Stimulating the interest of young girls in science and engineering to improve the [gender balance](#) in these careers.

ACTING FOR SUSTAINABLE DEVELOPMENT

ENSTA Bretagne trains future innovators, responsible engineers prepared to act for sustainable development.

In the first year, cross-disciplinary training is given on "An Engineer's Key Challenges", and this year the thematic focus was waste. The training continues in the engineering projects undertaken in the second and third year.

It is also at the heart of many mechanical science, information technology and human science research programs.

- The design of less energy consuming [transport](#) systems.
- The reduction of the environmental impact of [cities](#) and the encouragement of « intelligent » services.
- The detection of [pollution](#) on ocean surfaces.
- The development of marine [renewable](#) energies
- The measurement of the impact of climate change.
- The monitoring and tracking of [marine mammal](#) populations
- The heightening of student awareness of the need for sustainable development in all their engineering projects.
- Humanities research on training in [responsible innovation](#).



For more diversity in digital technology, female students are running workshops for female secondary school students ("L codent L créent" program).



ENSTA BRETAGNE

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