Space
THE LABS GIVING INNOVATION A BOOST

IMPACT
Alzheimer’s, Parkinson’s and multiple sclerosis...
Uniting for victory

COLLECTIVE INTELLIGENCE
Economics put to the human test

PROFILE
Nathalie Vergnolle, brain and guts
143 research laboratories
15 doctoral schools covering the entire range of disciplines
824 PhD degrees awarded in 2014-2015

5,934 researchers, incl. Ministry of National Education, Higher Education and Research (1,523), Public scientific and technological institutions (2,026), public industrial and commercial institutions (1,787), others (598)

3,082 academics from Ministry of National Education, Higher Education and Research

10,015 staff dedicated to teaching and research

6,873 administrative and technical staff

16,363 international students (representing 12.7% of enrolled students) of which 14.2% registered in exchange programmes

Fraction of students by grade level

Country breakdown

Type of training

Enrollments per academic year
with the fraction of students receiving a scholarship in each case

STUDENTS
100,000 students
29.8% scholarships students
47% male
53% female

INTERNATIONAL STUDENTS

RESEARCHERS & ACADEMICS

STAFF

www.univ-toulouse.fr
Space is playing an increasingly important role in all our lives, with satellite television, GPS and weather-forecasting being the three most obvious applications. But there are other less visible—yet no less important—uses, including help with decision-making in areas such as the environment, natural disasters, water resources and healthcare. The laboratories at the University of Toulouse are key players in all these developments. As you will see elsewhere in this new English version of Exploreur magazine, the region’s laboratories are playing a leading role in fields as diverse as Mars exploration, sustainable agriculture, space telecommunications and satellite protection. And what is the most valuable asset of our labs? The fact that they lie at the heart of a genuine ecosystem. In fact, Toulouse is the European leader in space technology: the sector employs 10,000 people, a quarter of the continent’s total workforce. The CNES technical centre—France’s space agency—is a major presence in the region together with, of course, those two industrial heavyweights: Airbus Defence and Space and Thales Alenia Space, which manufacture satellites. But there is also a host of companies of every imaginable size that have developed services linked to space technology and data. In addition, our engineering schools and universities run a variety of educational programmes adapted to the needs of these players, be that engineering degrees, Masters or PhDs. As for research, it is not just fundamental but also clearly has a technological purpose, as evidenced by numerous contracts signed with industry, particularly in the context of the Institut de recherche technologique Saint-Exupéry.1 None of this, however, would bear fruit without interdisciplinarity, which is the University of Toulouse’s very raison d’être. In the field of space technology, roboticists are working with planetary scientists, remote-sensing specialists with agronomists, and lawyers with economists... These marriages generate innovations, and innovative thinking that can be fed into society and the economy.

And what is true for the space sector is also true for other disciplines. In an increasingly complex world, we have to adopt original perspectives, broaden our approach and think ‘outside the box’. At the Institute for Advanced Study in Toulouse, anthropologists, economists, historians and philosophers are joining forces to establish a new discipline, ‘behavioural economics’, which will lead to a better understanding of our reflexes as consumers and the choices we make as citizens. In the health sector, specialists are gathered under one roof at the NeuroToul centre of excellence, their goal being to improve the fight against Parkinson’s and Alzheimer’s. And, faced with the growing public health concern that is inflammatory bowel disease, Nathalie Vergnolle (a talented researcher who is featured inside) is marshalling experts from all walks of life. At the University of Toulouse, we apply the principle that underlies rugby—our region’s favourite sport—to our research: where there is unity, there is strength.
There are only good reasons to do your PhD in Toulouse!

Toulouse, the best place to study in France

The École des Docteurs of the Université de Toulouse is the federation of 15 Doctoral schools, representing a total of 4,400 PhD students (40% international students), with 890 PhD awarded per year. It covers all scientific domains and it is located in the Occitanie region. The École des Docteurs offer languages classes (French as foreign language, English, ...) and a wide range of non-disciplinary training programs adapted to the PhD student needs. It has a unique dedicated PhD International Office, providing information, advice and support for PhD candidates. More informations: www.univ-toulouse.fr/phd
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Alzheimer’s, Parkinson’s and multiple sclerosis... Uniting for victory

BY JEAN-FRANÇOIS HAÏT

Alzheimer’s, Parkinson’s and multiple sclerosis are all major health issues, affecting more than one million people in France. Raymond Le Moign, director of the Toulouse University Hospital (CHU), opened the inauguration day and first NeuroToul scientific symposium on 14 April last year, when he immediately made it clear that ‘neurodegenerative diseases have become a national priority’. This Toulouse-based initiative brings together 13 different teams (see box) united by a single goal: to join forces to launch research projects in the field of neurodegenerative diseases.

The idea came in response to the call for tenders initiated throughout France as part of the 2014-2019 Neurodegenerative Diseases Plan. The scheme aims to break down research barriers, take a broad look at the diseases and create common ground between research, healthcare and medical and social welfare, explains Michel Clanet, former head of neurosciences at the Toulouse CHU and chair of the committee for monitoring the national plan.

NeuroToul is a virtual research centre that has received support from the Toulouse CHU to the tune of €100,000 a year. Internationally, it has been incorporated into the COEN network (Centres of Excellence in Neurodegeneration) alongside six other units in France. In total, nearly 100 researchers from Toulouse are involved in the project, where ‘multidisciplinary’ is the watchword. ‘It is an opportunity for teams that do not collaborate on a regular basis to work together. We can tackle new research hypotheses using original approaches,’ says Prof. Olivier Rascol, NeuroToul’s co-ordinator. Toulouse has several strong points in its favour, starting with its comprehensive research activities in the field of inflammation. Indeed, the issue of inflammation is being incorporated more and more into the study of neurodegenerative diseases. With Parkinson’s disease, for example, the death of the neurons triggers an inflammatory response, which in turn encourages the neuronal death to spread. Understanding the mechanisms at work and testing anti-inflammatory molecules that could slow down the progress of neurodegenerative diseases are two major goals. Toulouse can boast a second major strength: its expertise in clinical trials and cohorts. Large-scale studies have already been conducted in the city, such as the MAPT study that focused on prevention. However, an important objective of the Neurodegenerative Diseases Plan is to investigate very large cohorts so that we can have a better understanding of the diseases. NeuroToul will also include a pharmacovigilance centre for carrying out research into the side-effects of new drugs using an epidemiological approach. Furthermore, it will also open up to the world of economics. The centre approached Ambiotis, a Toulouse-based company that designs in vitro and in vivo models for inflammation mechanisms to test innovative molecules. NeuroToul has already embraced two projects. The first, funded by the MSD Avenir...
foundation, will study the risk of developing Alzheimer’s in a cohort of 400 frail subjects. The second, for which funding has yet to be finalized, will focus on neuro-inflammation and Alzheimer’s. It will study the progress of the disease in a cohort of patients (employing imaging techniques in particular) and perform a clinical trial for an anti-inflammatory molecule.

But NeuroToul does not begin and end with medicine. It also covers the human and social sciences, hosting researchers from the Toulouse School of Economics (TSE). ‘In this context, we are particularly interested in the idea of dependence,’ says Emmanuel Thibault, a professor at TSE. ‘With neurodegenerative conditions, relatives of the patient play a key role in helping out at home, giving their services for free. Although legislation on funding independence is in the pipeline, it has never been implemented. But managing dependence is a genuine challenge, and not just on a financial level. In fact, the mortality rate is abnormally high among caregivers.’ And this is the theme that TSE researchers have decided to investigate. Among other things, they have added questions to the questionnaires that healthcare facilities ask patients and relatives to complete. The aim is to flesh out the socioeconomic profile of caregivers and their motivations for helping (altruistic, financial, etc.). For instance, do caregivers in rural areas differ from those in urban environments?

Answering questions such as this would make it possible to target future public policies with greater accuracy. How, in short, can we support caregivers, and whom should we subsidize? ‘The aid given evolves over time,’ adds Emmanuel Thibault. ‘For, as long as dependence is relatively mild, patients prefer to be helped by relatives. When the condition gets worse, they prefer to call on professionals. At TSE, we are building theoretical models on this journey. Now we need field data, and NeuroToul will provide it.’ The human and social sciences took pride of place at the second science workshop held at the end of 2016 on the theme of the burden of helping.

ECONOMIC RESEARCHERS ARE FOCUSING ON DEPENDENCE

Olivier Rascol, NeuroToul co-ordinator.

Fluorescent marking of the Tau protein in an in vitro human neuronal cell. In Alzheimer’s disease, it accumulates in the neuron, which eventually dies.
Given that astronomers have already detected almost 3,500 exoplanets, isn’t this latest sighting just another exoplanet to add to the collection? No—nothing could be further from the truth! This new gas giant was first spotted by a team headed by Jean-François Donati from the Institut de recherche en astrophysique et planétologie at the Midi-Pyrénées Observatory (IRAP/OMP) together with his international partners. And it is a discovery so unique that it has even earned the honour of being reported in the international journal Nature.2 ‘This exoplanet revolves around V830 Tau, a star barely 2 million years old that is located 430 light years from earth,’ explains Donati. ‘If we compare its age to the life of an average human, it is as though we had observed a baby when it was just a week old.’ The team’s exoplanet bears witness to the still mysterious childhood years of the planetary systems. It was a slight variation in the star’s velocity that betrayed the existence of this enormous exoplanet whose orbit is very close to its star. In theory, however, this cousin of Jupiter should—like the largest known planet—orbit on the icy peripheries of the system. This is where the giant stars come into being, a mixture of gas and dust from the protoplanetary disk that surrounds new-born stars. This scenario, which is consistent with the architecture of the solar system, was turned upside down in 1995 when Michel Mayor and his colleagues at the University of Geneva discovered the first exoplanet. This gas giant was also orbiting near its star but was much older than V830 Tau, which gave rise to two hypotheses: the giants were propelled towards their stars by neighbouring planets (a migration that would take hundreds of millions of years). Alternatively, when the giants were formed, they were subjected to the gravitational influence of the protoplanetary disk, which propelled them towards the centre in under a million years. The discovery of the giant planet V830 Tau validates the latter hypothesis. ‘It is a highly significant outcome,’ explains Alessandro Morbidelli from the Côte d’Azur Observatory in Nice (OCA), who has developed a detailed model of how the solar system was formed. ‘It shows that at least some of the giant “hot” planets have reached their orbit by migrating within the protoplanetary disk.’ And it is a phenomenon that could also be relatively widespread: a second giant exoplanet, close to a young star, has been discovered by an American team.

The discovery of a huge exoplanet orbiting extremely close to a young star is shedding new light on how the planetary systems were formed.

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**A giant exoplanet: like a baby in its cradle**

BY **ANNE DEBROISE**

The giant exoplanet V830 Tau was identified using two instruments designed and built at IRAP/OMP to analyse light from the stars: the Narval and ESPaDOnS spectropolarimeters. The former is set up on the Bernard–Lyot telescope at the summit of the Pic du Midi, and the latter on the Canada-France-Hawaii telescope in Hawaii. The teams from IRAP/OMP are currently finalizing two new items of equipment: SPIRou and SPIP. Both are equipped with infrared vision, which will make it possible to observe the birth of stars and planets—and the planetary systems of certain stars close to the sun—with much greater visual acuity such that we may be able to uncover a twin for our own planet earth. Scheduled start-up: 2017 and 2019.

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**SPIROU AND SPIP: ON THE LOOK-OUT FOR NEW WORLDS**

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NANOELECTRONICS 
ON THE HORIZON

Ultrathin, transparent and foldable screens that hide their electronic components... that is the dream of laptop manufacturers the world over, and the answer lies in nanomaterials. But their properties still have to be extensively studied. This was the aim of Electron, a project launched as part of Labex Next. Two types of nano-objects have been synthesized: platinum nanostars with three branches measuring 200 nanometres (a billionth of a metre) and gold nanowires (1.5 nanometres in diameter). The researchers connected the nano-objects using gold electrodes in an attempt to answer a fundamental question: how do these objects transmit current, especially when subjected to magnetic fields? ‘The platinum stars have proved to be highly efficient conductors,’ explains Lise-Marie Lacroix, researcher at LPCNO and co-ordinator of Electron. ‘They could be used to make high-power micro-electronic connections. As for gold wires, they are promising but very fragile. We are working on a solution to make them more stable.’ The project has already resulted in two publications. JFH

JASON 3

TAKING A CLOSER LOOK 
AT THE CLIMATE

The Jason-3 satellite (CNES-NASA) went into space on 17 January. The satellite is the latest in a long line that started in 1992. More than 30 years of observations, in other words, that have led researchers to conclude that the rise in sea levels due to global warming has averaged 3.3 millimetres a year over the last two decades (with an uncertainty of 0.5 millimetres). The devil, however, is in the detail, as Benoit Meyssignac from Legos explains: ‘This uncertainty masks events that are still small but which, if they increase, could have an impact on climate change in the future.’ In the first instance, Siberia’s melting permafrost could have catastrophic consequences. Jason-3 is more accurate than its predecessors, and will reduce this uncertainty, meaning that it will be possible to detect these emerging phenomena so as to be prepared. JFH

A different perspective

THE DEVELOPMENT OF LAW IN EUROPE

Do Europe’s different systems of justice have a common history and shared roots? This is the question that galvanized participants during the first year of the Dikè series of seminars, the papers for which have just been published. Jean-Christophe Gaven, director of Toulouse’s Collège supérieur de droit, and the man behind the project, tells us more.

E: What does Dikè mean?
JCG: Dikè was a Greek goddess who personified human justice. Our project, which got off the ground in 2014, investigates the way justice systems have evolved in Europe from the Middle Ages to the present day. We invite legal historians, lawyers, sociologists and experts in private and public law and political science—from France and abroad—to take part in two or three days of collective thinking every year.

E: What themes do you tackle?
JCG: The first year was devoted to the foundations of justice. We asked whether the European systems of justice have a common source. Do we use the same symbols? This year, we will examine the concept of the supreme court. In France, it is about turning the Court of cassation into a supreme court, and it is interesting to look elsewhere and at other ages to understand the implications of such a change.

E: What now of your thinking?
JCG: We publish the lectures in a journal on the Internet. We also have an educational remit. Students can attend the seminar days, and a doctoral week that counts for the training at the École doctorale de droit et science politique. AD
**Immunotherapy**

**AN ALTERNATIVE TO CHEMOTHERAPY**

It is more effective and it is less aggressive: immunotherapy is in the process of replacing chemotherapy for a wide range of cancers. Julien Mazières, head of the thoracic cancer unit at Hôpital Larrey at Toulouse University Hospital (CHU), tells us more about immunotherapy’s success in treating lung cancer.

**Explorecr: What is the principle behind immunotherapy?**

**Julien Mazières:** Tumour cells express specific markers on their surface that our immune system can recognize and destroy. Cancer occurs when the cells manage to conceal these markers and proliferate without the immune system reacting. Immunotherapy blocks this masking mechanism, and wakes up the body’s natural defences. Unlike chemotherapy, this type of therapy only attacks cancerous cells and generates far fewer side-effects.

**E:** What kind of cancers can it be used on?

**JM:** Immunotherapy has proved to be effective initially on melanoma. But its indication is being extended to other tumours. In combination with the Toulouse Institut universitaire du cancer and the Toulouse CHU, we’ve been testing immunotherapy on lung cancer—which is a difficult cancer to treat—for four years. Our clinical trials show that immunotherapy can stop the cancer developing for a longer period and that it improves survival for longer than chemotherapy.

**E:** Does it work on all patients?

**JM:** No, unfortunately, it doesn’t. Only a third of patients respond to immunotherapy at the moment. Our goal now is to understand why this is the case and to pinpoint markers that will help us know in advance which patients it will benefit.

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**Neurons**

**SAFEGUARDING MEMORIES OF OLD**

Our brains might be able to preserve the memory of sounds or images they have not seen or heard for decades. That is the hypothesis being investigated by a team led by Simon Thorpe, director of the Centre cerveau et cognition (CERCO), as part of the European ‘M4’ project. Memories are believed to be encoded by a neural network whose connections are strengthened as we learn. A memory is subsequently consolidated (and possibly modified) each time it is activated. It was assumed that if there was no reactivation, the connection would weaken or die. To test this notion, the team selected opening credits of television shows from the 1950s to 1970s that had never been subsequently re-broadcast. ‘We showed them to around 30 participants aged between 70 and 90,’ explains Thorpe. ‘A number of them remembered the programmes, and knew what the shows were called or the main actors.’ How can we explain the longevity of these memories? ‘The brain may contain highly selective neurons that only respond to a specific stimulus. They might remain dormant for years until the same stimulus comes up again’ suggests Thorpe. At Hôpital Pierre-Paul-Riquet in Toulouse, surgeons insert tiny electrodes into epileptic patients’ brains, in order to identify the neurons that trigger seizures. CERCO then invites these patients to take part in memory tests in the hope to detect one of the neurons that preserve old memories.

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**Malaria**

**RESISTANCE ON THE RISE**

There have been fears that the parasite that causes malaria is becoming immune to the most effective molecule in the pharmacopoeia, artemisinin. But the work being carried out by a team led by Françoise Benoit-Vical at the CNRS Co-ordination Chemistry Laboratory presents an even grimmer picture: ‘We have grown parasites in the presence of artemisinin. After five years, the parasites are no longer sensitive to the molecule that should kill them but they have also learned to resist other anti-malaria molecules, even molecules they have never been exposed to.’

To achieve this multi-resistance, it seems that the parasite puts itself in a state of ‘quiescence’, meaning that it can wait until the end of the treatment before resuming its development. Scientists are now looking at ways to prevent the parasite from adopting this state. And the need is urgent: in late 2015, cases of artemisinin resistance were reported in five countries in South-East Asia.
**Surgical gauze**

**RESORBABLE AND 100% GREEN**

A surgical gauze that can be reabsorbed safely into the body has now become a reality. Sofradim Production, based in Trévoux, Ain, launched production of the gauze in late 2015. It is made of cellulose, and the process for treating it was developed by the supercritical fluid team at the Chemical Engineering Laboratory in Toulouse, led by Jean-Stéphane Condoret: ‘This type of gauze already existed but the solvents used to make it could pollute the gauze, which was then harmful to patients, carers and the environment. So, after ten years of research, we devised a process based on supercritical CO2 that is environmentally sound.’ And the result? A ‘greener’ gauze that also has improved healing and resorption qualities. AD

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**Catmag**

**STORING GREEN ENERGY**

Solar and wind energy have one big flaw: production periods (when the wind blows or the sun shines) do not necessarily correspond to peaks in consumption—hence the need to store energy. Bruno Chaudret, Marc Respaud and Julian Carrey from the Physics and Chemistry of nano-objects Laboratory in Toulouse have suggested using the energy to induce a magnetic field where organometallic nanoparticles heat up at great speed. This heat would then convert the carbon dioxide and hydrogen gas into methane. Dubbed CATMAG, this process has received support from the innovation incentive programme started by CNRS in 2014. It is now entering the pre-industrial phase with LEAF, a company based in Blanquefort in Gironde. AD

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**Developing bioethanol 2.0**

The Agro-Industrial Chemistry Laboratory is pursuing its efforts to produce second-generation bioethanol following the launch of the BABET-REAL European project. The lab is continuing a long-standing collaboration with the University of Mexico (UNAM) and 13 other partners from Europe and South America. The project leader is Gérard Vilarem, professor at INP-ENSIACET, who answers our questions about the programme below.

**Exploreur: What are the advantages of second-generation bioethanol?**

**GV:** It reuses waste from agriculture and the forestry industry. Unlike bioethanol made from corn grain or sugar cane, it does not compete with the food industry.

**Exploreur: What kind of technology are you using?**

**GV:** It is called ‘bio-extrusion’, a process we patented in 2012 that is faster and cheaper than conventional techniques. It involves fragmenting the biomass by forcing it through an extrusion device and then mixing it with the enzymes that will convert the cellulose into glucose before the fermentation that produces ethanol. Our partners in Mexico have adapted the process to blue agave bagasse, which is the residue left over from tequila manufacturing.

**Exploreur: How far advanced is BABET-REAL at the moment?**

**GV:** The number ‘5’ in the title indicates the TRL (technology readiness level), with 9 being the highest and signifying a marketable technology. The previous project, BABETHANOL—which was at level 4—demonstrated the feasibility of each production stage. BABET-REAL 5 should lead to the creation of between one and three industrial pilots. These will be located in Europe or South America, close to areas where the raw materials are produced, whether it is fibrous residue from agave, grain stalks or eucalyptus. AD
Baudelaire Song Project

What do David Bowie, Claude Debussy, the French rock band Alcest and the rappers LPI have in common? They have all been inspired by Charles Baudelaire. Mylène Dubiau from the LLA laboratory at Université Toulouse – Jean Jaurès embarked on the Baudelaire Song Project with a British colleague in an attempt to identify who has been influenced by the nineteenth-century poet.

Explorer: Where did the idea for the Baudelaire Song Project come from?

Mylène Dubiau: I was working with Helen Abbott, who has a PhD in literature from the research centre in Sheffield, on the influence of Verlaine and Mallarmé on French melody. It was then that we realized that Baudelaire’s impact on music has been particularly strong for two centuries. He was a revolutionary in terms of the subjects he tackled: night, death and orientalism to name but three. These are all themes that we still enjoy a great deal today but at the time Les Fleurs du mal created a scandal. Yet there are not very many on-line resources or they are not very comprehensive.

E: In what way is the project original?

MD: It is interdisciplinary. We are pinpointing influences at a thematic level and on the structure of the words and music: a drum solo, a modulation or a change of accompaniment may signal the succession of two lines. We are devising analytical methods and are using software that identifies these musical markers on recordings, and we have already made an inventory of 800 passages! How Beautiful You Are by The Cure is a translation of Les Yeux des pauvres; David Bowie borrowed the idea that ‘il faut vous enivrer sans trêve’—drinking relentlessly—for his Rock’n’Roll Suicide; and LPI wrote about Baudelaire’s Le Mort joyeux—‘The Grateful Dead’.

E: What are you going to do with the data you collect?

MD: There will be an on-line database that will provide access to recordings, poems, analyses and stylistic data. Internet users will be able to see the musical markers, the themes that are repeated, and how the influences are distributed across the world—all research that has been handed to a postdoc student. Last of all, our project has a participatory dimension: everyone is invited to tell us about any track influenced by Baudelaire that they might have uncovered! CP

www.baudelairesong.org

Two ears

FOR ONE SOUND

Honk!... When our ears hear a simple sound, not only can they identify what kind of sound it is (a cry, ringing, voice or explosion, for example) but also its origin or source. Understanding the mechanisms behind this prodigious ability is one of the goals of the European TwoEars project, which was made up of ten research teams until it came to an end in late 2016. ‘We have developed a model of human auditory perception that includes all the mechanisms involved,’ says Patrick Danès, project director at the CNRS Laboratoire d’analyse et d’architecture des systèmes (LAAS-CNRS). ‘We think of hearing as an active, exploratory process.’ And it is a process that involves round trips between hearing, the different levels for processing the information in the nervous system (reflex and intelligent analyses) and head movements. The software suite produced by the research can be used by a robot to analyze an auditory scene, and is now available on the project website. The LAAS-CNRS roboticists, for their part, have kitted out a model that can actively locate a sound source. AD

The dark side

OF THE MARKETS

Bruno Bias and Fanny Declerck, researchers at CRM and the Toulouse School of Economics, organized a seminar entitled ‘Trading and investment in opaque markets’ on 22 September 2016 at the Fédération bancaire française in Paris. ‘Opaque markets are financial markets where bonds and shares are bought and sold. Although they are legal, they do not comply with the rules for transparency imposed on markets for Euronext-type shares,’ explains Declerck. On these ‘over-the-counter markets’, investors themselves have to compete with several ‘traders’, mostly by telephone, to find out the purchase or selling prices—but without any information on past transactions. These opaque markets, which are on the rise, now account for 90% of bond exchanges and 40% of share exchanges. They raise questions such as: are the negotiated prices fair or do they distort the market? What would happen if legislation was passed for enforcing greater transparency on these transactions in Europe? Collecting information by asking traders and the Autorité des marchés financiers for confidential data should help the researchers answer these questions. AD
A team from Toulouse used the EuroScience Open Forum held in Manchester, England, from 24 to 27 July, to find out all about what is needed to make a success of the event when it is hosted in the Pink City in 2018.

**ESOF: Manchester hands the baton to Toulouse**

Graphene, synthetic biology, big data, science and emerging countries, researchers and social networks, women in science—the choice of themes ranged far and wide for participants at the July EuroScience Open Forum (ESOF) in Manchester. All the events were held under one roof in the spectacular Manchester Central Convention Complex, housed in a former railway station in the heart of a city rich in outstanding architecture dating back to the Industrial Revolution.

In 2018, it will be Toulouse’s turn to host the event, which has been run under the auspices of EuroScience since 2004. The Toulouse ESOF team for 2018 was in attendance in Manchester, accompanied by a city and national delegation. They took the opportunity to learn about organizing such an event before the British passed them the ESOF baton at the closing ceremony. ‘We were impressed by the multifaceted nature of the forum: not just the wide variety of scientific papers but also a fair with exhibitors from all types of background—institutions, laboratories, manufacturers, publishers and the like’, said Anne Cambon-Thomsen, the ‘champion’ or standard-bearer for ESOF 2018 in Toulouse. ‘Every aspect of science was represented: basic and applied research, innovation, and careers in the academic and private sectors,’ adds Philippe Raimbault, president of Université Fédérale Toulouse Midi-Pyrénées. Several researchers from Toulouse also made the trip, including Isabelle Serça, who presented the ‘ProusTime’ project (see Exploreur N°2, p. 9), a multidisciplinary exploration of time in the works of Marcel Proust.

The same multidisciplinary approach was much in evidence in Manchester alongside a window on the entire world, with a significant presence from Japan and South Africa, for example. Several sessions were devoted to science diplomacy. ‘This is a very interesting area that we will expand on in Toulouse,’ said Cambon-Thomsen. Six doctoral students were also part of the Toulouse delegation. They acted as ambassadors for Toulouse and ESOF ‘beta testers’ at Manchester Central and for ‘Science in the City’, where all the events were designed for the general public. Everybody enjoyed an “interesting mix in a magical venue”, and were particularly responsive to the careers aspect of the forum: the opportunity to network, specialised sessions with titles such as Life after a PhD or Pi with the Prof., when young doctoral students could discuss issues with a senior researcher over an informal lunch. In terms of the wider public, a science slam was held at city hall, where young scientists tried to win over the audience in a short timeslot—another event that gained support from everybody. The doctoral students from Toulouse are now full of great ideas for the 2018 ESOF in the city. ‘We need to open up our labs, increase the different types of interactive events and present original scientific papers. Toulouse and Midi-Pyrénées have an enormous potential!’

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2. The ESOF ‘champion’ is the scientist who leads the project.  
4. Four doctoral students received funding from the Doctoral School, and two from the Toulouse Laboratoire de génie chimique - LGC - INP Toulouse, Université Toulouse III – Paul Sabatier, CNRS.
It has been over ten years now since Toulouse—known familiarly as the ‘Pink City’ for the color of its brick walls—has been transported to the Red Planet, aka Mars. Has teleportation been invented? No, science has not made that giant leap yet! But as our special report shows, the laboratories in the Midi-Pyrénées region of southern France are giving space technology a massive boost. And the focus is not just on pure research into the planets: the labs are also investigating the highly-applied field of telecommunications, where a new generation of satellites is creating a new set of problems. As for earth observation, the aim is to devise innovative solutions for more sustainable forms of agriculture and to improve our management of water resources. But this research would not see the light of day—and would not be prized economically and socially—if the laboratories did not lie at the heart of a veritable regional ecosystem that also includes CNES, universities, engineering schools and industrial partners. The prosperity of the space sector also requires a deep understanding of the profound changes taking place in the industry, which is exactly the role being performed by a corporate chair named after the brightest star in the sky: Sirius.

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The SEIS seismometer flight model, part of the Insight mission, being prepared for thermal vacuum tests in July 2015, at Intespace in Toulouse.
Could NASA manage without the Pink City in its attempts to conquer the Red Planet? Of course not! The US space agency has been turning to Toulouse’s laboratories for over a decade to design and manufacture the major instruments that kit out its Mars orbiters, rovers and landers. It all started 15 years ago when CNES and the Institut de recherche en astrophysique et planétologie (IRAP) designed and manufactured ChemCam. This instrument was used to equip Curiosity, the rover for the Mars science laboratory mission launched in 2011, which is currently exploring the foothills of Mt Sharp on Mars. ChemCam uses laser shots to remotely analyze the chemical composition of rocks. Its success was very much to CNES’s advantage, with NASA choosing the French space agency to manufacture SuperCam, an instrument for analyzing rock that will be fitted to the Mars 2020 rover. This mission will be of the utmost importance to the future of science, since it will undertake the preparations for returning samples from Mars. ‘The future rover is designed to find samples containing possible traces of previous life, then to collect and store them on Mars until another mission arrives to bring them back to earth,’ says Pierre-Yves Meslin, assistant professor at Université Toulouse III – Paul Sabatier and researcher at IRAP, which will produce SuperCam for CNES in partnership with the US Los Alamos National laboratory. CNES is also responsible for manufacturing the SEIS seismometer for NASA’s Insight mission, which will take off in 2018. The goal of the mission is to study the internal structure of the Red Planet. The body responsible for the instrument is the Institut de physique du globe in Paris (IPGP), which is heading up an international team and is working with the ISAE-SU.
PAERO engineering school in Toulouse. As David Mimoun, research professor in space systems at ISAE-SUPAERO, explains: ‘We have numerically modelled all the problems that SEIS could experience on Mars so that IPGP and its partners can design the instrument and its software.’ From MSL and MAVEN to Insight, ExoMars and Mars 2020, Toulouse has been aboard all the missions to Mars! What is the secret of the region’s success? The answer lies in the fact that Toulouse and its environs are home to the four essential requirements of the space industry: research laboratories; national research centres (such as ONERA) and the national agency (CNES); industrial manufacturers; and specialized teaching in the universities and engineering schools. And all of these players are in constant interaction. So, in terms of training, the research-based Masters 2 in astrophysics, space and planetary sciences (ASEP) is jointly accredited by ISAE-SUPAERO and UPS. This means that engineering students can familiarize themselves with space research and, for some, continue their studies with a PhD, especially at IRAP. The links are strong with industry since those two aerospace giants, Airbus Defence and Space and Thales Alenia Space, are based in Toulouse together with a number of micro, small and medium-sized firms (see box). For ChemCam, CNES and IRAP turned to Thales, where Éric Durand—head of the optronics programme—recalls: ‘We were the only people with a laser that was suitable for CNES’s needs for ChemCam. But we had to modify it to the particular problems encountered in space and on Mars. We combined Thales’s laser expertise with IRAP’s specialist skills in instrumentation and CNES’s space know-how to achieve our goals.’

This collaboration is continuing today with SuperCam. The prototype of this remote-sensing instrument is currently in the testing phase in one of IRAP’s cleanrooms. ‘If everything goes according to plan, we will manufacture and test the qualification model later this year,’ says Pierre-Yves. ‘If the trials are successful, we will make the flight model for delivery in 2018.’ And another chapter in the conquest of Mars will have been written in the Toulouse region.

The Insight probe, which carries CNES’s SEIS seismometer, is shown here in a cleanroom at Lockheed Martin Space Systems in Denver (Colorado). Take-off, which was scheduled for 2016, was postponed until 2018 to finalize the instrument.

58 researchers and engineers presented themselves as candidates for Mars 2020... just 7 were selected.

70 is the number of full-time equivalent staff mobilized by SuperCam in and around Toulouse.

5 manufacturers out of collaborating on SuperCam are based in Haute-Garonne.

$130 million NASA’s forecast budget for the instruments for the March 2020 rover, including SuperCam.
Thousands of satellites need protecting in space

Space is constantly bombarded by particles that are hazardous to satellites. Jean-François Roussel and Sophie Duzellier at ONERA are investigating the impact of these particles. Their aim? To protect the new generation of electrically-powered and low-cost constellation satellites.

**Exploreur:** Why is space so dangerous for satellites?

**Jean-François Roussel:** Because the earth has a magnetic field whose influence extends thousands of kilometres into space. This field captures protons and electrons emitted by the sun together with other particles from deep space travelling at high speed. Satellites are regularly struck by these streams of particles, which can lead to some serious damage.

**E:** What kind of damage?

**JFR:** To the internal electronics; for example, a particle that strikes an electronic component causes localized ionisation. This results in, for instance, an over-exposed pixel on the image taken by a camera, or a data error in a memory. Or worse still, it can lead to the destructive failure of an electronic component that is short-circuited. But the doses of particles received also accumulate, which adversely affects the performance of the components over time.

**Sophie Duzellier:** In addition, there is external damage. The particles generate destructive electrical discharges on the solar panels of the satellites.

**E:** How do you study these phenomena at ONERA?

**JFR:** In the space environment department, we use physical models depicting the behaviour of atoms bombarded by particles, both for one-off collisions and for slow continuous exposure. Our aim is two-fold: to design predictive models that will help industry understand how the components in their future satellites will withstand this threat; and to calculate the best possible size for their protection systems. Because every gram counts in space!

**SD:** Using particle accelerators in our laboratories, we can simulate in three months the effects that the surface of a geostationary satellite will be exposed to in 20 years! We also measure the actual flow of particles at the spot where they reach the ground: at the Pic du Midi in France, in Brazil and in Antarctica.

**E:** We have known for a long time that satellites are subject to these effects. Are there any new challenges to studying them?

**SD:** Yes, because the satellite constellations dedicated to the Web, such as O3B, are going to grow. They are based on an affordable business model, meaning that they will be built using commercial components that are not necessarily designed for space. Will they be able to resist the effects of the particles? The challenge for us will be to develop specific tests for these increasingly high-performance components whose make-up we do not know very well.

**JFR:** A telecom satellite today has to carry half its weight in fuel so that it can reach its geostationary orbit at 36,000 km. So the cost is very high. To bring it down, operators are relying on small electric-propulsion motors to put the satellites into orbit. But they will be much slower, which means that they will be bombarded by particles for a longer period of time. How will they behave? That is what we want to know.

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1. Director of the DESP department - space environment at ONERA.
2. Head of the Electronics and Materials Unit - DESP department - space environment at ONERA.
3. Satellite operator with Google as a shareholder. The satellites are built by Thales Alenia Space (31 launched since 2013 and 8 ordered).
The laser that is revolutionizing space telecoms

Will broadband soon be available everywhere and for everyone? It is a distinct possibility thanks to laser-based satellite communications. Angélique Rissons at ISAE-SUPAERO is working on the sensitive development of this new technology, which Google and Facebook are very keen on exploiting.

**Explorecur** Why use lasers for satellite communications?

**Angélique Rissons**: There has been an explosion in the demand for mobile phones and broadband Internet services. But many parts of the world are not covered by wired telecommunication networks—this is the infamous ‘digital divide’. There are conventional telecommunication satellites, which use radio frequencies, to solve the problem. But the difficulty is that there are a great many operators and a limited frequency band. The speed is not high enough: 4G should provide 1 GB/s in the downlink, whereas under current conditions we have 300 MB/s.\(^1\) However, broadband requirements are a thousand or even a million times higher. Hence the idea of using laser technology, which poses no problem for the frequency band, since the beam has a very fine focus from one point to another. And it gives a much higher speed than conventional radio frequencies without generating any additional electromagnetic pollution.

**E**: What is your research at ISAE-SUPAERO looking at?

**AR**: In the Optoelectronics, Electronics and Signal Department, I am working on modulating laser signals in conjunction with the Complex Systems Engineering Department. The information you need to convey has to be encoded in the light beam, which you achieve by superimposing an electrical signal on it. The problem is doing this in such a way that the modulated signal loses as little information as possible between the satellite, which is in geostationary orbit at 36,000 km, and the receiver on the ground, which is a kind of small telescope. We are working on the latter with ONERA and the Institut de recherche technologique Saint-Exupéry (IRT).

**E**: Has the technology already been tested?

**AR**: Yes, in the 2000s, the European Space Agency (ESA) tested the laser communication between the Artemis and SPOT 4 satellites as part of the SILEX project. ESA is now deploying the EDRS satellite network. They communicate with each other via laser and relay data to the geostationary satellites that send it back to the ground. But laser technology from space to the ground is not yet fully developed. We are working on the Nimph nanosatellite project that will help us test and qualify the amplifiers—electronic devices that give the lasers their power. In addition, as part of the ALBS (broadband access via satellite) project with Saint-Exupéry IRT, we are designing a platform that will help us test the laser on the ground. It will work by generating an optical signal and simulating all the turbulence that might be encountered while crossing the atmosphere.

**E**: When do you think laser space telecommunication will become operational?

**AR**: By 2020, I think. The technology is creating enormous interest among the major operators. Google and Facebook have hundreds of satellite constellation projects. Closing the digital divide could be a very lucrative market, and so it is becoming a highly sensitive subject. Even our doctoral theses on the topic are confidential! **E**

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1. GB/s: gigabit per second. 1 gigabit = 1 billion bits. MB/s: megabit per second. 1 megabit = 1 million bits.
Feature

Remote sensing:
Making agriculture more sustainable

Spatial data can make a valuable contribution to a range of agricultural and farming initiatives: saving water resources, limiting sources of input pollution and putting agro-ecology into practice, all of which are reflected in the research carried out in the laboratories in the Toulouse region.

By Pascal Nguyễn

Will space technology one day be able to preserve—or even boost—harvests while moving towards a more sustainable model that uses fewer inputs (fertilizers and pesticides) and less water? In fact, this is already in part the case. Satellite positioning systems are widely used to manage inputs in so-called ‘precision agriculture’. However, the advice given to farmers has certain limitations: for example, it is only relevant to managing inputs on large plots of land. Furthermore, the measurements provided by optical satellites are too infrequent and dependent on cloud cover. The researchers in Toulouse are looking to take their work a stage further so that in the future they will be able to offer large and small farmers alike an improved service—as well as benefiting the environment. The idea is to enhance the spatial accuracy and frequency of measurements to provide information not only on a specific plot of land but also on its immediate environment. Another objective is to be in a position to measure the water stocks available and the requirements for crops at each stage of their development.

For example, the Centre d’études spatiales de la biosphère (CESBIO) has developed the capacity to produce accurate land-use maps derived from spatial data. ‘We have designed approaches that cover entire regions,’ says Yann Kerr, director of the Centre, ‘and we know what grows where.’ The laboratory can also use the same satellite images to identify the leaf

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1. Centre d’études spatiales de la biosphère - CESBIO - CNES, CNRS, Université Toulouse III – Paul Sabatier, IRD. • 2. Leaf area index: the ratio of the total upper leaf area to the area of soil on which the vegetation grows. • 3. REGARD project - Modelling water resources in the Garonne basin: the interaction between natural and anthropogenic components and the contribution made by remote sensing (CNRM-GAME, ACT, ECOLAB, IMFT/IMT, LEGOS, CERFACS and BRGM). • 4. SMOS mission to study soil hydration, ‘Vegetation’ instrument on
area index for vegetation with ever greater precision. Researchers have used this data to generate growth models for crops and their requirements. CESBIO is analysing water resources in an area that extends over much of South-West France. ‘Thanks to the satellite and modeling,’ continues Kerr, ‘we can assess and monitor the amount of water in the soil that is available for plants up to a depth of one metre, which is the depth that roots reach in conventional farming.’ The laboratory is also taking an active part in the REGARD project, launched in 2014 with the aim of monitoring evolving water resources in the Adour-Garonne basin on a daily basis, as well as the interaction with the atmosphere and farming. By exploiting information on the water supply and the stage of vegetation development, the researchers can pinpoint the specific needs of a crop at a given moment. The result is that irrigation should only be carried out when necessary. For all these developments, CESBIO uses satellite data such as SPOT from CNES or Airbus DS or NASA’s Landsat. But the lab can also help space agencies devise missions to meet specific needs, such as data on vegetation cover or soil moisture. This data can help reduce the use of fertilizers and pesticides, which is a major issue from an environmental perspective and in economic terms for farmers. It is also one of the applications of the research carried out in the Dynafor laboratory at INRA.

Data from space is being utilized to study the ecology of the landscape and to understand how it influences the presence of certain animal and plant species, with a particular focus on what takes place around agricultural acreages. ‘Studying so-called semi-natural elements, such as grass strips, hedgerows or woods—and their diversity in the vicinity of crops—can help identify the factors that promote the development of crop aids such as hoverflies, which feed on pests,’ explains David Sheeren, a specialist in remote sensing applied to landscape ecology at Dynafor. By making the surrounding areas more suitable for hosting aids, it should be possible to reduce the need for insecticides through biological control. However, improvements still need to be made to the way the information contained in the images is exploited. This task is being tackled by a mixed team consisting of Dynafor, CESBIO and Toulouse’s Institut de recherche en informatique (IRIT/ TÉSA) as part of the MUESLI project. The lab is also harnessing satellite images for experiments in the forestry sector, the aim being to create an inventory of the different tree species in collaboration with the Centre national de la propriété forestière (CNPF) over an area of 24 km by 24 km near Saint-Lys (Haute-Garonne). The goal of the research is to design operational applications that will assist farmers and foresters in their work. Yann Kerr gives a glimpse of this future: ‘If there is enough investment and if water resources do not change so much that they end up challenging the models under development, these tools may be available in the short term, even within a few years’.

WE HAVE THE ABILITY TO EVALUATE AND MONITOR THE AMOUNT OF WATER IN THE SOIL

Image area (110 x 100 km²) taken by the Sentinel 2 satellite over the Toulouse region, 3 December, 2015. The image is repeated every five days in order to monitor crop growth. On this image from December, most of the plots are still covered in bare soil.

Geography

OPERATIONAL SPACE

CESBIO and Dynafor are taking part in a thematic cluster on land surfaces known as Thèia, launched in late 2012, which combines a number of agencies (CNES, IGN, INRA, ONERA, Météo-France, CIRAD, etc.). The goal is to provide value-added spatial data—that is processed in such a way that it can be used by everybody, especially for developing applications. It is an initiative that calls to mind Mercator Océan (see 2015 English issue, p. 30) but for use on dry land. The initial outcomes include land-use maps that can be used, for example, in the world of agriculture and by forest managers.

Understanding the radical changes in the space industry

In an age of globalized services, conquering space is no longer simply a question of technology. Financing space programmes, managing the careers of technicians and drawing up international space law... these are all issues addressed by the Sirius chair on behalf of the major space operators.

BY CAMILLE PONS

What are the consequences for the space sector when Web billionaires invest in the industry? How can technical experience be transmitted, and how can we avoid losing skills on programmes that sometimes run for many years? The 1967 Washington Treaty enshrined the principle of a space accessible to one and all. But who is responsible if there is an accident or when space debris hits a satellite, for example (see box)? Because the laws governing these activities are certainly not homogeneous. These are just some of the questions facing twenty or so researchers at Université Toulouse Capitole and Toulouse Business School (TBS) as part of the Sirius—Space Institute for Research on Innovative Uses of Satellites—chair. Sirius partners the universities with three heavyweights from the space sector in Toulouse: CNES, Thales Alenia Space and Airbus Defence and Space.

WHEN IT COMES TO SPACE LAW AND MANAGEMENT, THERE IS NOT NECESSARILY ONE SINGLE ANSWER

Lucien Rapp is a professor at UT Capitole and a legal expert in the space industry and telecommunications. Rapp, who is also the chair’s scientific director, stresses that the partnership aims to provide industry with ‘food for thought and decision-making’ on social issues which, because the sector is changing so rapidly, will shape their proper development. ‘While it is true that research articles on these topics have already been published elsewhere, we do not think that they go into enough depth or they are too optimistic,’ suggests Thierry Duhamel, head of R&D for the Space Systems Unit for France at Airbus Defence and Space. ‘In law, as in management, there is not necessarily a single answer. The Sirius chair offers a second take on certain issues.’ Among the major themes to be tackled is the question of how the sector is financed. The time when space was explored using only public funds is over, and we are now living in an era where private services are developing: not just GPS, mobile communications and television but also vehicle, fleet and coastal monitoring as well as systems for piloting missiles and drones. ‘The commercialisation of space is creating a new economic model, where consumers are becoming financiers. We have to investigate the consequences for the space sector.’ Sirius’s research focuses on, for example, the potential impact of venture capital on the industry. Google, Apple, Amazon and Facebook have already invested in projects with a view to earning a return on their investment. Google has put $1 billion into the US aerospace company SpaceX (a competitor to Arianespace) to launch small satellites. ‘These platforms are entering a monopoly sector and are changing the rules of the game’, according to Rapp. Another central issue facing the space sector is career manage-
ment, which is no simple matter given that a space programme can last several years, a timespan that is hardly compatible with skills management. ‘Careers cannot be fixed over 20 or 30 years. And the different programmes have varying business plans: when there’s a high number of orders, everyone is assigned; when there are fewer business plans, they are assigned to other programmes.’ says Victor dos Santos Paulino, head of the chair and management studies at TBS. ‘It is about finding ways to organize the transmission of experience from one employee to another when you have these movements back and forth.’ Finally, there is the proliferation of space laws over the last ten or so years. It is a fairly logical trend, insofar as most space law is based on international treaties adopted in the late 1960s that have now become obsolete. The chair is examining the content of these laws and the need to define an international standard to avoid sovereignty shocks,’ says Rapp. Knowledge is shared on the Sirius site dedicated to the chair or via meetings such as the annual ‘Law and Space’ workshops. ‘The idea is to feed information into the space community in its broadest sense,’ says dos Santos Paulino. It is no coincidence that the Sirius chair was set up in Toulouse, the capital of aeronautics and space, since the region combines local services and research development in areas where synergies are still rare. ‘It is a highly virtuous circle,’ says Rapp. ‘On the one hand, research attracts resources, and on the other, partners see that the issues that are of interest to them are targeted for in-depth study’

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Space debris

CAN WASTE COLLECTION BE MADE PROFITABLE?

‘Space really is a dustbin and it is appalling! The debris is totally uncontrollable and is spinning in an orbit at over 25 000 km/h!’ exclaims Lucien Rapp, scientific director of the Sirius chair. It is estimated that there are over one million items of debris: disused satellites, the upper stages of launchers, paint chips, bolts, batteries and tools lost by astronauts—all of which threaten to strike operational satellites with significant economic consequences. NASA has assessed the potential risk at 30 collisions a day, and the amount of debris is steadily growing. There is a solution, however: launch missions to clean up space. Technical solutions exist but manufacturers still have to be motivated by the prospect of profitability. A team of researchers from Sirius will test an economic model for collecting waste later this year.
**Silvia Villarreal Soto**

**THESIS:** New fermented beverages and food made from plants: the impact of the process on quality

*Exploreur: Tell us a little about your thesis subject.*

**Silvia Villarreal Soto:** I am working on a drink called kombucha which comes from Asia and is made from fermented black tea. The fermentation is caused by a special combination of bacteria and yeasts that release a number of compounds that have interesting properties. They are antioxidant, for instance, as well as being anti-inflammatory and anti-diabetic. But there is not a lot of information on active components in kombucha and how they change during the fermentation process. The aim of my thesis at the Chemical Engineering Laboratory is to streamline the production of kombucha and monitor its quality. I am also trying to identify what microorganisms are present. I am working with Symbiotec, a local firm in the Toulouse region.

*E: Why did you choose Toulouse for your PhD?*

**SVS:** I initially trained as a biochemical engineer in Mexico, where I was born, before doing a Masters 2 in new product development at the University of Bonn in Germany. I had already learned French, and I am also interested in your culture and gastronomy! There are university agreements between Mexico and France, and I discovered that the MEGEP doctoral school runs a wide range of unusual projects in agronomy, engineering, energy, aeronautics and the like.

*E: Do you see your future career in research or industry?*

**SVS:** It is a bit too early to decide. We are expecting to begin publishing articles on my work in 2017, and we are going to strengthen ties with industry. We will be focusing on testing the combination of yeasts and bacteria on other plants to create new products. After that, everything will depend on what opportunities arise. But I am passionate about research and I would like to work as a lecturer and researcher. And why not in Toulouse? It is a city I love! I have become a Toulousaine at heart!

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**Theofilos Papadopoulos**

**THESIS:** The role of miRNAs in kidney diseases

*Exploreur: Tell us a little about your thesis subject.*

**Theofilos Papadopoulos:** My work focuses on detecting chronic kidney disease, which is rising sharply worldwide. It is a disease that is linked to lifestyle, things like hypertension, diabetes, obesity and smoking. It harms the kidney over time but it is already too late when the symptoms appear. At the Institute of Metabolic and Cardiovascular Diseases, we are looking for markers that can help us spot the disease at an early stage. My thesis looks at one of these markers, called miRNAs or miRNAs for short. These are small RNA molecules whose job is to regulate gene expression. They can be detected in urine in differing amounts depending on whether the patient is in a stable condition or whether the disease is spreading. My goal is to develop an indicator based on these microRNAs that will one day enable us to diagnose the disease, and to say whether it can be controlled by medication or if dialysis or a kidney transplant is needed.

*E: You have just presented your thesis; can you remember any high point during the past three years?*

**TP:** Yes, there was a very delicate analysis that was carried out with a Dutch colleague. We had to extract microRNAs from really small urine samples. I was very nervous because it was the first time that we had tried this method. And it worked! But in the future a test will only be viable—and will only be able to be marketed—if it can be performed on small samples.

*E: How do you see your career progressing?*

**TP:** I came to Toulouse thanks to a European Marie Curie grant. Now I am mainly looking for a postdoctoral fellowship so I can continue along the same path. But I could also see myself in the R&D department of an industrial pharmaceutical company or as a science technology advisor since I love interacting with people.

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**Graduate School: Mechanics, Energy, Civil Engineering, Processes (MEGEP).**

**Laboratory:** Laboratoire de génie chimique - LGC CNRS, INP Toulouse, Université Toulouse III – Paul Sabatier

**Getting involved with Mexican farmers in Durango, my home town, to help improve the traditional production of wine using pomegranate juice.**

**silviaslejandra.villarrealsoeto@ensiacet.fr**

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**Graduate School: Biology, Health, Biotechnology (BSB).**

**Laboratory:** Institute of Metabolic and Cardiovascular Diseases (IM2C) INSERM, Université Toulouse III – Paul Sabatier

**Being involved in Toulouse’s International PhD Students Association, which welcomes foreign students and offers practical and cultural information on Toulouse and the surrounding area.**

**theofilos.papadopoulos@INSERM.fr**
As we experience more and more hot spells as a result of global warming, fruit and vegetable yields are plummeting, and some tomato crops are falling by as much as 70 to 90 per cent," warns Mondher Bouzayen, head of the Genomics and Biotechnology of Fruit Laboratory, jointly run by Toulouse’s INP and INRA, the French National Institute for Agricultural Research. Yet, some types of tomato have a natural resistance to heat. The only problem is that these are wild varieties with no economic value: the quality of the fruit is poor and some are not even edible. But could we not identify what it is that makes them resistant to high temperatures and replicate this quality in commercial varieties?

This is the aim of the TomGEM project, set up following a successful bid to the European Union. Launched in March 2015, the venture will receive a total of €5.6 million in funding over a four-year period and has attracted the involvement of 18 partners (laboratories in Europe, Taiwan and Argentina), as well as seed producers and producer associations. Everything is co-ordinated by Mondher Bouzayen, whose laboratory took part in the tomato genome sequencing project in 2012. For Bouzayen, the tomato was the obvious choice: with 160 million tonnes produced in 2012 according to the Food and Agriculture Organization of the United Nations (FAO), it comes second only to the potato in terms of global consumption. It is also the ideal crop: ‘Tomatoes are easy to grow and their reproduction cycle is very short—only two to three months—which means that they can be harvested more than once a year, so the effects of cross-fertilization can be seen in a relatively short space of time.’

The TomGEM researchers are planning to work from rustic varieties, listed in seed banks both in Europe and further afield, such as at the University of Buenos Aires in Argentina (where the oldest varieties of this originally South American fruit can be found) and the Maritsa Vegetable Crops Research Institute in Plovdiv, Bulgaria. But they will also take inspiration from varieties adapted to a tropical climate, developed by institutions in Taiwan. ‘We are going to identify which varieties have a pollen that can fertilize flowers and produce fruits at a high temperature. This step is key to successful yields in hot climates,’ explains Antonio Gradell-Richart, a researcher at the Institute for Plant Molecular and Cell Biology (IBMCP) in Valencia, Spain. These varieties will then be sequenced to identify the genes responsible for this resistance.

Findings will be passed on to the seed producers, who will then be able to cross-fertilize them with particular ‘elite’ varieties (with a high commercial value) and develop lines that will achieve good yields, taste delicious, have a high nutritional content, and be able to withstand periods of searing heat.

The transfer of genes from one organism to another, even through natural cross-fertilization (rather than genetic manipulation) is a regular source of controversy: to whom do the transferred sequences belong? The local populations or the seed producers? What can actually be patented? Have any potential allergens been introduced? To help guide future decisions, INP Toulouse is compiling a detailed record of all gene transfers performed.
What do economics, biology, cognitive science and history have in common? Not a lot, it might seem, at least at first sight, apart from the fact that they all relate to one and the same subject: humans as social animals. It was recognizing this need to combine knowledge from each of these disciplines and to revive research topics in the social sciences that brought the Institute for Advanced Study in Toulouse (IAST) about in 2011. The Institute is linked to Toulouse School of Economics (TSE), and for a very good reason: it was no other than the economist and 2014 Nobel Prize winner, Jean Tirole, who set the project in motion, inspired by the prestigious Institute for Advanced Study at Princeton University (New Jersey, USA). To address various growing issues in today’s world, such as our ability to adapt to the depletion of natural resources, or the influence of religion on a particular decision or public policy, we need to draw on skills from different disciplines. Economics, with all of its theoretical models, needs to stop turning a blind eye to the humanities and other social sciences,’ explains Paul Seabright, professor at TSE at Université Toulouse Capitole. Nine disciplines are now studied at the Institute: law, anthropology, biology, economics, history, philosophy, political science, psychology and sociology. ‘Economics needs to make use of anthropological and sociological research to find out what is happening in the real world, and also look at work by psychologists and biologists to help decode human behaviour,’ Seabright continues. This is a field known as ‘behavioural economics, which focuses on the observation of human beings to explain our choices as ‘economic agents’.

Ingela Alger, senior researcher at the National Centre for Scientific Research (CNRS) and head of the biology programme at the IAST, works in this area. Her research examines the way in which our moral and altruistic motivations evolve over the long term. Using mathematical models developed in the field of evolutionary biology, Alger has been able to show how people with an altruistic personality have come out tops in the natural selection game. ‘A better knowledge of people’s intrinsic motivations, such as altruism and morality, can be very useful when it comes to economics or politics—for introducing environmental measures in a more effective way or managing public goods, for example,’ she explains. Alger is currently studying trends in family relationships, with a particular focus on...
Collective intelligence

Among them, Heidi Colleran is working on the evolution of fertility and, specifically, the motivations that lead parents to choose to have one or more children in transitioning societies. For economists, the fertility rate is directly linked to a society’s standard of living. However, as our research in Poland has shown, the mechanism for choosing the number of children is actually much more complex: it is a combination of a personal decision and various cultural and structural factors, which also play a key role. This clearly illustrates how anthropology can help us gain a better understanding of demographic transition mechanisms. So it definitely has a role to play in economics, where it introduces different ways of thinking, as alternatives to the dominant productivist model. Colleran has published several articles on the subject and will shortly be joining the Max Planck Institute in Jena, Germany. On a different note, Jean-François Bonnefon, senior researcher in cognitive psychology at CNRS, is currently completing a project on ‘algorithmic morality’, prompted by the emergence of autonomous cars. Together with two US researchers, he conducted an on-line survey to ask 1,000 people the following question: in the event of an unavoidable accident, should the car be programmed to save the driver, even if it means hitting one or more pedestrians, or to sacrifice the driver’s life to save the pedestrians? These questions are far from anecdotal as they embrace both moral and ethical issues, which will ultimately be key to marketing and promoting this new technology. Bonnefon explains.

One of the Institute’s core activities involves organizing seminars and conferences, not only to keep in step with the latest research but also to encourage dialogue between disciplines. The organization of ‘Tuesday lunches’ has also proven to be very popular. Researchers at IAST are regularly invited to present their latest work to their peers on an informal basis. ‘This is not a straightforward exercise,’ says Bonnefon, ‘because you have to explain your project in a different way, using language that can be understood across all of the disciplines, and you also have to be open to criticisms and suggestions. That is what helps you rethink your own discipline.’

According to Ingela Alger’s research, altruistic people are the real winners in natural selection.

Paul Seabright, Director of IAST.

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37 publications in peer-reviewed journals
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Emmanuelle Rial-Sebbag
Bioethics explorer

Reconciling individual rights with ever-accelerating advances in biomedical research: this is the vocation of Emmanuelle Rial-Sebbag, a health law and bioethics expert working with researchers at INSERM, the French National Institute of Health and Medical Research.

INTERVIEW BY CARINA LOUART

Explorer: You are INSERM’s only researcher in health law and bioethics across the country. Why did you choose this field?

Emmanuelle Rial-Sebbag: Because using parts of the human body for research and health care is an issue that involves both fundamental rights and individual rights, and raises specific ethical questions as a result. These issues are directly linked to my training in international public law. In 2009, I met Anne Cambon-Thomsen, who leads the ‘Genetics and Society’ platform in Toulouse. She spawned my interest in the law surrounding the use of human samples—blood, cells, tissue, organs, and so on—and in DNA and biobanks. I wrote my thesis on this area.¹ Now that I am working in the research laboratories, I am in a much better position to identify the legal and ethical issues raised by biotechnological innovations.

Explorer: What role do you play alongside the researchers?

Emmanuelle Rial-Sebbag: I offer guidance when they are planning new projects, to make sure their work adheres to an existing legal framework. For instance, using biological samples from children is governed by very strict rules. Obviously, it is important to make sure that the researchers do not become subject to sanctions or have their work invalidated but, more generally, they need to be encouraged to think about their research from an ethical point of view. We are also developing independent research on the legal and ethical challenges associated with new health technologies and their impact on public health.

Explorer: You are involved in several biobank projects. What kinds of challenge do they pose?

Emmanuelle Rial-Sebbag: Using biological samples is one of the driving forces behind biomedical innovation, especially in the area of regenerative medicine, which requires the use of stem cells.² So, since 2013, I have been co-ordinating a European research project called EUCELLEX, to evaluate regulations on their use.³ At the moment, these samples are stored in biobanks, which need to be governed by an ethical and legal framework. For example, what happens if someone wants to use a sample for a different field of research from the one the donor originally gave his or her consent for? Or to design a commercial product? And what about sharing the associated data across national borders, such as the donor’s age, or gender, or medical history? All of these questions are still waiting for answers!

Explorer: When you think about how quickly biotechnological innovations are advancing, ethics and the law seem to be lagging behind.

Emmanuelle Rial-Sebbag: Yes, because biotechnologies are becoming increasingly difficult to grasp. The National Research Agency’s Biobank project (2012-2020), in which I am involved, is aiming to harmonize all of the French biological resource centres through a single access portal, which will address all of these issues.

Emmanuelle Rial-Sebbag has recently co-authored a practical guide with Gauthier Chassang and Anne Cambon-Thomsen, entitled Éthique et réglementation des biobanques de recherche (‘Ethics and Regulation of Biobanks for Research’), which examines the required procedures for obtaining or using biological resources in an ethical way. The guide is available from the Biobanques website, under ‘Publications’.

¹ http://thesesups.ups-tlse.fr/663
² A form of treatment that involves ‘repairing, replacing or regenerating’ damaged, diseased or ageing cells, tissue or organs, particularly through the use of stem cells.³ https://www.eucellex.eu/about-eucellex⁴ http://www.biobanques.eu/fr
In France, we are good at doing research but not so good at promoting it. Toulouse White Biotechnology is there to bring the right mix of scientists and funding sources together,’ says Pierre Monsan with a grin. As founder and director of TWB, Monsan opened 1,700 m² of new offices and laboratories at the Parc technologique du Canal in Ramonville, near Toulouse, on 7 June 2016. White biotechnologies are so-called because they rely on natural processes.

In other words, they use living organisms to explore alternatives to fossil carbon and to reduce the amount of pollution caused by the mass production of biofuels, agri-food products and pharmaceuticals, for example. The services unit was launched in 2012 as part of France’s Investments for the Future Programme. Operating under the auspices of the National Institute for Agricultural Research (INRA), the National Institute of Applied Sciences (INSA) and the National Centre for Scientific Research (CNRS), with public funding for its infrastructures, the unit is aim is to promote ideas quickly and shorten the gap between the drawing board and industrial application. To achieve this, it takes its roots from a completely new model. First of all, it draws on the long-standing research carried out at Toulouse’s Biosystems and Process Engineering Laboratory (LISBP), which specializes in life science applications. ‘This laboratory already had a strong partnership culture with industry,’ says Monsan, who contributes to its work. A bonus indeed, given that TWB is governed by both public bodies and private businesses. In fact, it has 30 partner companies, ranging from multinationals, such as Total and L’Oréal, to SMEs.

Research can take any one of three forms. The first, involving private and confidential work, is defined according to the needs of the companies concerned, who retain the intellectual property rights for their findings. The second is a combined public and private solution, whereby the intellectual property is shared. One example of this is Thanaplast, a project backed by a company called Carbios, with private and public partners, the aim being to design a new generation of biodegradable plastics. ‘We entrusted the LISBP and TWB with all of our preliminary research. And three years on, we are almost at the industrial application stage,’ says Jean-Claude Lumaret, MD of Carbios. As for the third type of research, TWB alone leads ‘high-risk’ projects, as the results are somewhat tentative. This is funded by private partners, but the return on investment is potentially very high. To date, 19 projects have been funded, seven patents filed and one start-up created in the form of EnobraQ, a company set up in 2015. Stemming from research carried out at the LISBP, EnobraQ is putting its money on yeast. Commonly used to make bread, beer and wine, this micro-organism could acquire—through genetic modification—the ability to absorb the CO₂ emitted by polluting industrial processes, such as cement production, and turn it into biofuel or molecules of interest. ‘We were able to benefit from a fully equipped laboratory from the start. This meant that we could quickly obtain the proof of concept we needed to raise €2.9 million in April last year,’ explains Cédric Boisart, EnobraQ’s director of R&D. As well as the laboratories, the hosted companies also benefit from advanced technological platforms, specially designed to accelerate research. Of particular note, TWB has been re-

### Nurturing start-ups in biotechnologies

Toulouse White Biotechnology opened the doors to its new offices and laboratories on 7 June 2016. Here we take a look at a unique public structure, a halfway house between research and business, that takes its shape from an inventive new model.

**BY JEAN-FRANÇOIS HAÏT**

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2. Biosystems and Process Engineering Laboratory (LISBP), CNRS, INSA Toulouse, INRA.
3. Carbios, Barbier Group, Ulice, Deinove – CNRS, INRA and the University of Poitiers.
sponsible for the development of two custom-made ‘robots’. The first is able to produce bacterial or yeast strains very quickly, through genetic modification, and detect targeted properties in certain types. The second is used for cultivating micro-organisms in parallel, to test the ability of different selected strains to produce molecules of interest. The cultures can then be tested in near-industrial conditions in fermentation reactors (vessels for cultivating bacteria or yeast) with capacities of up to 300 litres. ‘We are providing the client with pre-industrial batches and a process manual,’ explains Michel Manach, director of Industrial Partnerships at TWB. ‘The technology readiness level is now 5 or 6. So the company can then justify its high investment for scaling up.’ TWB seems to be getting its mix right: the contracts signed by the end of 2016 amount to €19 million in total, the aim being to achieve €21 million in 2019. ‘We’ll continue to operate on the principle that one euro invested is one euro earned,’ Monsan concludes. ‘And we’re also looking to broaden our pool of partner companies.’

1700 m²
of work space

7
specialized platforms

79
projects between 2012 and 2016

90
contributors, 20 of them permanent

€19 million
worth of contracts by the end of 2016

4. Technology readiness level, commonly known as TRL, is a measure of the distance between the product at the point it has reached in its design phase, and its mass manufacture. The industrial production phase is level 9.
Short Bio

1968
Born in Agen (Lot-et-Garonne)

1997
• Thesis on pathophysiology, Université Toulouse III – Paul Sabatier, Toulouse
• Postdoctorate, University of Calgary, Canada

2000
Assistant and then associate professor, University of Calgary, Canada

Since 2007
Director of research at INSERM’s Department of Immunology and Infectious Diseases, Toulouse

2013
• Knight of the Legion of Honour
• Receives the Women in Inflammation Science Award

2016
Heads the new Digestive Health Research Institute
Rubor et tumor cum calor et dolor... ‘It means redness and swelling with heat and pain. Did you know that? It was Celsus, a Roman medical practitioner, who defined inflammation 2,000 years ago. And his definition is still valid today!’ Nathalie Vergnolle smiles and apologizes for the untidiness of her rather modest new office at the University Hospital of Purpan, where she officially opened the Digestive Health Research Institute on 1 January 2016, taking up the position as director. Although she has barely had the chance to settle in, photos of her children adorn her desk. There is also a calendar on the wall, marked with places like Paris, Cancun, Croatia, California, and other destinations hosting conferences and colloquia, packing a schedule that already looks full at the beginning of January. This is the price that the 47-year old senior researcher at INSERM has to pay for the international reputation she has established in the field of inflammatory gastrointestinal diseases.

Long considered to be the unglamorous side of medical research—the heart and brain being favourites—it seems that guts are now de rigueur. Gut: The Inside Story of our Body’s Most Under-Rated Organ, a popular science book written by German PhD student Giulia Enders, is clear testimony to this, having sold around 1 million copies in Germany alone.3 This is an interest betraying a genuine public health concern: ‘We have seen a growing occurrence of inflammatory bowel diseases over the last few years,’ Vergnolle points out. ‘Inflammation is normal,’ she clearly explains. ‘It is a way for the body to protect itself against stress. It is an alarm signal.’ But when this inflammation becomes disproportionate and will not go away, then there is a problem. This can result in inflammatory bowel diseases (IBD), such as haemorrhagic rectocolitis or Crohn’s disease, both of which are very painful and debilitating. They also cause tissue necrosis and, in the most serious cases, part of the intestine has to be removed. Around 150,000 people in France are affected.2 Inflammation can also lead to less serious illnesses, such as irritable bowel syndrome, which causes chronic diarrhoea. ‘Up to 20% of the population is affected to varying degrees,’ she says.3 And on top of that, sufferers experience a constant discomfort, often accompanied by a feeling of embarrassment that prevents them from...
talking about it or seeking professional help. Until recently, the matter was quickly closed, with symptoms being attributed to psychological causes, and a prescription handed over for antidepressants. And for quite an understandable reason: the brain and the intestine have more in common than you might think. ‘The intestine is an extraordinary organ containing a great many neurons and receptors. It is like a second brain that is directly linked to the first. It also contains billions of bacteria, whose role we still do not know a great deal about. We have not got to the bottom of the mystery yet,’ Vergnolle explains. Understanding how the human body works has always been her driving force. Born into a ‘working-class family, and relying on grants based on social criteria’, she failed her first year as a medical student but, inspired by a human pathophysiology professor, took an interest in this area. Her diploma of advanced studies took her by chance to INRA’s Pharmacology Station in Saint-Martin-du-Touch, where she worked in Lionel Bueno’s laboratory. Bueno’s research focused on the digestive contractions of the intestine in animals and humans, before his death in 2015. ‘An outstanding scientist,’ she acknowledges, but an extremely demanding hard worker. Another notable figure at the lab was Jean Fioramonti, a man ‘with an extraordinary scientific culture and work ethic’ who also sadly left us in 2015. The working conditions were hard, but the team always pulled together. This taught the young Vergnolle how to manage others: ‘You have to know how to make decisions but always listen at the same time,’ she says. This is confirmed by Claude Knauf, university professor, INSERM researcher and specialist in the gut-to-brain axis, who has also joined the Institute: ‘She seems to spend countless hours discussing things with the researchers and technicians.’ Above all, Vergnolle prefers to have more easy-going relationships with her colleagues, something that she finds all too rare in Europe, but which she very much appreciated in Canada. In 1997, after completing her thesis, she applied for a post-doctoral position at the University of Calgary, in the Inflammation Research Group. ‘I saw this young woman arrive, who had only been married for a couple of days. She was bright and cultured, and needed very little supervision. In fact, she was the best postdoc I ever worked with,’ says John Wallace, who led the group for 20 years.

On hearing these words, her face is overcome by rubor et calor, although there is no sign of tumor or dolor, she simply blushes, as she often does when someone sings her praises. Vergnolle modestly puts it down to the ‘luck factor’: luck that her supervisors in Canada let her ‘have babies’ by hiring a technician to assist with her research, luck that she fell across a discipline where all the groundwork had yet to be laid, and luck that John Wallace assigned her to an area that was to offer considerable scope: P4Rs (protease-activated receptors). Scientists had an idea that these receptors, made up of proteins and found in various parts of the body, might play a kind of alarm role. ‘Did they have some kind of link with inflammation, particularly in the digestive system, and if so, through what mechanism? ‘I kept going round in circles until one day, at a conference, I came across a poster showing the presence of these receptors on neurons.’ And then, bingo!

‘These receptors probably activate neurons, which then release neuropeptides, and subsequently cause inflammation!’ exclaims the woman who sees ‘research as a game, rather like a police investigation’. The publication of her findings in Nature Medicine in 2000 announced the beginning of her reputation and gave rise to thousands of projects in the same area. As a result of this work, the University of Calgary offered her an assistant professorship, and it was not until 2007 that she returned to France, thanks to the Bettencourt-Schueller Foundation, which helps talented researchers move back to their roots. Since then, her desire to build has never ceased. As well as the Institute, she is launching a new Masters programme in digestive health with Claude Knauf in Toulouse. And her next project will be to create a unique platform in France for producing ‘organoids’. This will involve using stem cells cultivated in a laboratory to recreate perfectly functional miniature organs—the intestines, the pancreas, the bladder—for research purposes. Finally, she also works as a consultant with major pharmaceutical companies, ‘because she has always had a great concern for relieving patients’ pain,’ says Knauf. Vergnolle confides that, away from the lab, she is ‘a mum first and foremost’. Her little remaining spare time is devoted to supporting the Toulouse Chamber Orchestra, which is run by a close family member, and spreading its music to places where it normally would not be heard, such as hospitals and prisons. She also takes part in regional, scientific and cultural initiatives, to reach out to others and pass things on. ‘That is what gives me the energy to keep going.’ You could also say: to have brain and guts.

4. A receptor is a protein, which initiates a cell response when it receives specific stimuli.
5. Advanced Technology Institute of Life Sciences (ITAV) – Université Toulouse III – Paul Sabatier, CNRS.
Université Fédérale Toulouse Midi-Pyrénées

HIGHER EDUCATION INSTITUTIONS

• Université Toulouse Capitole
• Université Toulouse - Jean Jaurès
• Université Toulouse III - Paul Sabatier
• Institut National Polytechnique de Toulouse
  - École Nationale Supérieure Agronomique de Toulouse
  - École Nationale Supérieure d’Électrotechnique, d’Électronique, d’Informatique, d’Hydraulique et des Télécommunications
  - École Nationale Supérieure des Ingénieurs en Arts Chimiques et Technologiques
  - École Nationale d’Ingénieurs de Tarbes
  - École Nationale de Météorologie
  - École d’Ingénieurs de Purpan
  - Institut National des Sciences Appliquées de Toulouse
  - Institut Supérieur de l’Aéronautique et de l’Espace
  - École Nationale de l’Aviation Civile
  - École Nationale Supérieure d’Architecture de Toulouse
  - École Nationale Supérieure de Formation de l’Enseignement Agricole
  - École Nationale Supérieure des Mines d’Albi-Carmaux
  - École Nationale Vétérinaire de Toulouse
  - Institut National Universitaire Champollion
  - Sciences Po Toulouse
  - Centre de Ressources, d’Expertise et de Performance Sportives
  - Institut Catholique d’Arts et Métiers de Toulouse
  - Institut supérieur des arts de Toulouse
  - Toulouse Business School

RESEARCH ORGANISATIONS

• Centre National de la Recherche Scientifique, CNRS
• Institut National de la Recherche Agronomique, Inra
• Institut National de la Santé et de la Recherche Médicale, Inserm
• Institut de Recherche pour le Développement, IRD
• Office National d’Études et de Recherches Aérospatiales, ONERA
• Centre National d’Études Spatiales, CNES