TOWARDS A MORE SUSTAINABLE, RESILIENT AND DIGITAL SOCIETY

ANNUAL REPORT 2021

LUXEMBOURG
INSTITUTE OF SCIENCE
AND TECHNOLOGY

LIST

LIST
TECH
DAY
2021
Claude Meisch
Minister of Higher Education and Research
LIST
TECH
DAY
2021

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A FEW WORDS FROM THE CHAIR OF THE BOARD OF DIRECTORS AND THE CEO

TOWARDS A MORE SUSTAINABLE, RESILIENT AND DIGITAL SOCIETY

Dear Readers,

For the past two years, the world has been experiencing a series of unusually grave crises of unprecedented scope. The COVID-19 pandemic and Russia's aggression against Ukraine point to the extreme fragility of geopolitical balances, the low resilience of global supply chains and the interdependence of the global economy. They also highlight how infinitely complex decisions have become for both public and private decision-makers. Health, migration, geopolitical, security and environmental challenges: our decision-makers are sailing on rough waters.

Nevertheless, a crisis also represents an opportunity to rethink systems to make them more robust. The lessons learned from these head-on crises must, above all, enable us to speed up the transitions necessary to avert a more insidious climate crisis, a crisis with far greater impacts, as demonstrated by the sixth Intergovernmental Panel on Climate Change (IPCC) report, published in April 2022, which calls for immediate action to secure "a liveable future".

A new world is emerging whose watchword will be resilience. This is what occupies Europe at present, and this is where LIST's mission comes into its own. At LIST, we strive to respond to global challenges, and to build a society that is simultaneously more resilient, sustainable and digital. LIST brings together diverse and complementary skills in the fields of information and communication technologies, environmental technologies, biotechnologies, advanced materials and space resources. This unique collection of skills makes it possible to create the synergies that are essential for building a reinvented economy and society.

Therefore, in 2021, we continued to develop high-impact technologies, whilst intensifying our 'sustainable by design' approach. In other words by striving to minimise the negative impact on the environment through the smart design of our products, services and technologies. It is in this vein that LIST formalised its LIST 2.0 strategy in the Multi-year Work Programme (MAP) 2022-2025, published in late 2021. This strategy reflects LIST's vision, mission and values, and takes the form of eight objectives and their indicators, enabling LIST to increase its economic, political, environmental, social, regional and academic impact.

In terms of partnerships, in 2021, LIST continued its extensive collaboration with the manufacturer Goodyear in the fields of sustainable mobility and materials of the future. Furthermore, it has signed a partnership with CircuitFoil to work on the next generation of copper foils. Finally, the signing of partnerships with Air Liquide/CNES and Airbus Defence and Space will contribute to the R&D activities of the European Space Resources Innovation Centre (ESRIC), implemented as LIST's fourth department.

In line with its mission to transfer innovation, LIST has created the spin-off Dynaccurate, whose aim is the automated interoperability of data and which facilitates the maintenance of large-scale knowledge graphs.

From an institutional point of view, LIST has continued to put its expertise to good use in the fight against coronavirus, in particular through the implementation of the CORONASTEP project, aimed at detecting the presence of the virus in waste water. LIST has consolidated this monitoring within the framework of a new project, CORONAVAR, aimed at detecting some ten variants of concern of the COVID-19 virus. In the aftermath of the flooding that struck Luxembourg and Europe in the summer of 2021, LIST provided maps based on spatial data showing the affected urban areas, both regionally and internationally. Essential support that once again demonstrates our societal contribution in response to the incidents and events the authorities must confront.

Finally, scientific excellence still remains the cornerstone of LIST's ambitions, as attested to by 106 national competitive projects, 50 international competitive projects and 170 collaborative projects in progress in 2021, as well as 146 scientific publications produced in the top 10% in their category, and 28 successfully-defended theses.

In this annual report, you will find evidence of our unwavering commitment to reinventing society, and guaranteeing the future for forthcoming generations and our planet: innovative research projects, unique infrastructures and testimonials from our partners. We are particularly proud to introduce you to the women and men who work behind the scenes on these success stories. We have chosen to shine a spotlight on our employees, who come to LIST from the four corners of the globe to push forward the boundaries of research. They are the first ambassadors of this sustainable, digital and resilient society that we wish to build hand in hand with our partners.

Eva Kremer
Chair of the Board of Directors

Dr Thomas Kallstenius
CEO

KEY FIGURES

HUMAN RESOURCES

As at 31/12/2021

662 employees

66% men

34% women

52 nationalities

77% researchers or innovation experts

For the entirety of 2021

95 people recruited in 2021

108 PhD students hosted at LIST in 2021

SCIENCE AND TRANSFER

30 PATENTS FILED

17 paid licences

238 scientific articles in 1st quartile journals

1 spin-off

R&D PROJECTS IN PROGRESS IN 2021

106 competitive national projects

49 competitive European projects

1 competitive international project (outside the EU)

7.49% of income from service provision

170 collaborative projects and similar

∑ 432 RDI projects and contracts in total

RESEARCH CONTRACT TYPES

- Competitive projects are research projects that have successfully undergone an international scientific evaluation following a call for projects under national or international programmes.
- Collaborative projects are research projects involving effective collaboration between at least two independent parties seeking a common goal based on a division of labour. The two parties jointly define the scope of the project, contribute to its execution, and share its risks and results.

  Projects falling under public utility missions entrusted to LIST and European Space Agency (ESA) projects, as well as those co-funded by foundations, have been classed as collaborative projects.

INTERNATIONAL COLLABORATIONS

NUMBER OF CONTRACTS IN PROGRESS PER COUNTRY

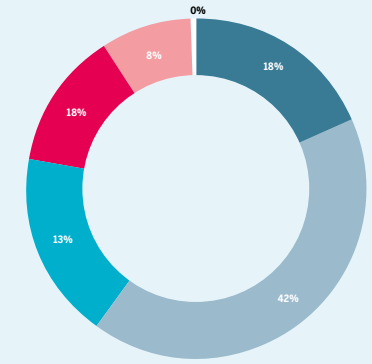
EUROPEAN UNION (EU)

France	100
Belgium	75
Spain	74
Germany	73
Italy	63
The Netherlands	37
Greece	35
Portugal	29
Austria	27
Finland	14
Poland	14
Denmark	13
Hungary	13
Bulgaria	11
Slovenia	11
Ireland	10
Sweden	10
Croatia	9
Lithuania	6
Latvia	5
Romania	4
Slovakia	4
Malta	2
Cyprus	1
Estonia	1
Czech Republic	1

REST OF THE WORLD

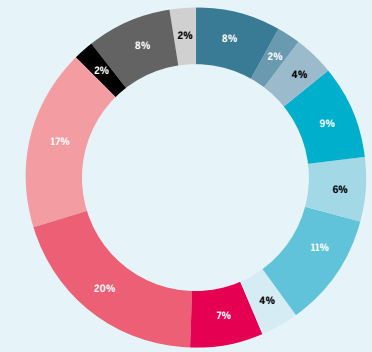
United Kingdom	42
Switzerland	6
United States of America	5
Israel	2
Norway	2
Turkey	2
Iceland	1
Japan	1
Uruguay	1

BREAKDOWN OF PARTNERSHIPS IN PROGRESS IN 2021 BY PARTNER TYPE



- Universities (133)
- Companies (299)
- Research centres (129)
- Public institutions (94)
- Foundations and associations (61)
- Other (3)

MARKET COVERAGE OF PARTNERSHIPS IN PROGRESS IN 2021



- Agro and natural resources (75)
- Automotive/aeronautical (19)
- Biotech/Cleantech (34)
- Construction (81)
- Education technology (55)
- Energy (97)
- Health and medical technology (32)
- Domestic security (65)
- ICT (177)
- Industry (155)
- Logistics (17)
- Mobility (73)
- Space (21)

OUR COMMITMENTS

OUR COMMITMENTS

DIVERSITY AND INCLUSION

At LIST, we strongly believe in the benefits of an inclusive culture. LIST's approach goes beyond diversity and inclusion in terms of gender and ethnicity to take account of differences in a broad sense. LIST makes a commitment to all its employees and partners that it will promote a company culture in which everyone can contribute their strengths and skills to LIST's strategy, and develop their potential, regardless of their ethnicity, beliefs, age, gender or sexual orientation. This approach not only makes it possible to improve the creativity, innovation and performance of our teams, but also to attract and retain new talent.

In 2021, LIST made Diversity and Inclusion (D&I) one of its priorities: a D&I Manager, Sabina Quijano, was appointed in January. LIST has drafted a Diversity Charter, committed to participating in the Positive Actions programme of the Luxembourg Ministry of Equality between Women and Men (MEGA), signed the Diversity Charter of the public body Inspiring More Sustainability (IMS), publicly supported Luxembourg Pride Week, launched a harassment project, and conducted many campaigns both internally and externally.

Sabina Quijano

ETHICS AT LIST

The European Commission encourages the development and implementation of responsible research and innovation practices, with the aim of promoting inclusive and sustainable research and innovation. LIST is committed to this approach and has adopted a Code of Ethics that collates the principles guiding how its research and innovation activities, and its commercial and administrative practices, are carried out. These principles form the basis for evaluating our organisation's projects, plans and practices.

Launched in 2021, the Ethics Committee, an independent, non-decision-making body, provides confidential advice to LIST's CEO. It can be activated by all LIST employees. Composed of five members for four years, in 2021, the committee elected Benoît Otjacques as its Chair and Catarina Araujo as Vice-Chair.

Among the principles covered by the Code of Ethics are research integrity, social responsibility, the protection of and respect for research participants and life, data protection and management, the protection of researchers and the research environment, the dissemination of research and its results, the dual use of research and innovation, risk prevention in the field of information technology and information sciences, and respect for the conflict of interest policy.

Catarina Texeira d'Araujo and Benoit Otjacques

Elorri Igos, Christina Ehlert and Anne Body

LIST: SUSTAINABLE DESIGN

Climate change, loss of biodiversity, the use of non-renewable resources, growth of inequality: within the scientific community there is no doubt how urgent it is to take action. At LIST, we are committed to setting an example, both in our research activities and in our day-to-day operations. The first efforts were launched in 2019 through the creation of the Sustainability working group. In 2020, we completed an in-depth assessment of our carbon footprint using the Greenhouse Gas Protocol international standard. We have analysed the impact of each of our operations, from our buildings to our procurement, consumption and even mobility habits.

This first phase has already allowed us to make and implement several recommendations. In 2021, LIST set a target of reducing its emissions by 24% by 2025, and adopted a multi-year plan with two different KPIs and related targets.

By adopting 'Sustainable by Design' as a LIST value, we recognise the importance of taking the entire life cycle of a product or service into account in order to ensure a truly sustainable approach. To avoid any harmful bias or indirect effects, we must take the design, production, use and end-of-life phases of any product into consideration, including new technologies. A reduction in the use of raw materials and an increased use of recycled or recyclable, biological or biodegradable materials are among the environmental criteria assessed by our researchers when defining projects.

ENSURING INFORMATION SECURITY

In order to protect its information assets, in 2021 LIST introduced a general information security policy. In the context of LIST's activities, information security is a major challenge in terms of confidentiality, integrity, availability and traceability. Ensuring security is an issue for both LIST's information assets (scientific, technical, administrative and strategic data), as well as those provided by its partners.

While technological and industrial espionage has always existed, the events of recent years show that the risk of espionage by foreign countries targeting research organisations is rising sharply. The inappropriate use of LIST data is likely to damage the image and competitiveness of LIST and its partners and, more broadly, the scientific and economic potential of the Grand Duchy of Luxembourg. In a global context of digitisation, and of interconnections or sub-contracting, many vulnerabilities can arise and compromise the security of LIST's data.

In order to continually improve its security level, LIST has based its approach on the ISO/IEC 27000 series of information security standards, as well as on other internationally recognised documentation, such as the publications of the NIST (National Institute of Standards and Technology) and the CIS (Center for Internet Security) controls.

Stephen Amolo and Pascal Graissaguel

OUR RESEARCH

1. SUPPORTING INDUSTRY AND POLICY MAKERS IN THE TRANSITION TO CARBON NEUTRALITY

> « Changing our individual behaviours through, for example, vegetarianism, soft mobility and buying second-hand products helps reduce our personal climate impact by around 20-30%, which is clearly an important step in the right direction, but sadly not enough. Reducing the remainder of our carbon footprint therefore lies in collective action. »
>
> Thomas Gibon,
> environmental life cycle analysis researcher

We provide industry and policy makers with a scientific assessment of the impacts and risks associated with the manufacture of products and technologies, consumption patterns, energy systems and the built urban environment. Our research focuses on developing integrated environmental and social impact indicators, assessing the (eco)toxicity of chemicals and materials, developing smart solutions for sustainable cities and supporting the development of environmental policies. We apply our expertise at each decision-making level (from substances to materials, products, technologies, services and territories), across a broad range of economic sectors, including the manufacturing industry, the processing and service industries, agriculture, town and country planning, mobility, building and construction, and energy production and distribution. The end goal is to support the ecological and energy transition of our society towards the 2050 carbon-neutral goals.

Success story 1

ESTIMATING THE CARBON FOOTPRINT OF LUXEMBOURG RESIDENTS

How should our economy, our lifestyles and our governance processes evolve in order to leave the fossil fuel era behind? The team, that Claudia Hitaj and Thomas Gibon are a part of, believes that technological progress alone will not guarantee the necessary ecological transition. Without downplaying the benefits of many technological advances, the aim is to explore the prospects of a more structural transformation of our society, of its economic, social, political and anthropological orientation. Within the framework of the Luxembourg in Transition competition, an international consultation launched by the Luxembourg Ministry of Energy and Spatial Planning, the team presented its plan for a carbon-free and resilient future for Luxembourg, and was chosen as one of the competition's four winning teams. For the competition, the team estimated the carbon footprint of Luxembourg residents and how a number of decarbonisation measures in the mobility, housing, agriculture and food sectors could help achieve the aim of reducing the carbon footprint from 15 to 1.6 tonnes of CO_2 eq. per person, per year, to comply with the Paris Climate Accords. The results of this project will be crucial for various follow-up projects at the national and international levels, and will serve as a basis for various awareness-raising activities.

Thomas Gibon & Claudia Hitaj

Success story 2

COMMITTING TO A CAUSE: LIFE CYCLE ANALYSIS

In May 2021, Thomas Schaubroeck received the SETAC Europe Award 2021 presented each year by the Society of Environmental Toxicology and Chemistry (SETAC) to recognise and honour the outstanding contributions of individuals or groups to environmental sciences and society. Thomas's efforts in the development and application of life cycle assessment have thus been recognised. Life cycle assessment consists of developing scientific indicators and tools that enable a holistic assessment to be made of the performance of products, technologies and policies in the field of sustainability, in order to meet the needs of industry and policy makers. A quantitative assessment of sustainability requires highly cross-cutting and interdisciplinary research, including stakeholder participation techniques. In parallel to Thomas's efforts to advance science and the public dissemination of his work through publications, journals and scientific conferences, he has been involved in the practical application of life cycle assessment in industry-related activities, such as waste water treatment, floor covering systems and food. Finally, Thomas has a passion for teaching and has been an active lecturer on life cycle assessment for two years, in addition to guiding master's and PhD students in completing dissertations and theses on this subject.

Thomas Schaubroeck

Tommaso Serchi, Arno Biwer, Ruth Moeller & Arno Gutleb

Success story 3

LIST'S ENVIRONMENTAL EXPERTISE BENEFITING THE OECD

From clothing to cars and furniture, product design often involves the use of chemicals or nanomaterials with various compositions. Before being launched on the international market, they must be subject to well-defined tests and regulations that guarantee their safety from both a health and an environmental perspective.

Appointed in 2021 by the Luxembourg Ministry of the Environment, Climate and Sustainable Development, four LIST researchers work on these issues as part of three groups of the Chemicals and Biotechnology Committee of the Organisation for Economic Cooperation and Development (OECD). Therefore, alongside international specialists, Arno Biwer, Arno Gutleb, Tommaso Serchi and Ruth Moeller put their considerable expertise to good use to promote the recognition and pooling of testing, standards, best practices and environmental regulations on an international scale.

This international distinction recognises the regulatory, scientific and technical skills of LIST researchers in managing hazards and exposure, as well as the risks inherent to chemicals, or any other so-called product of concern. For many years the Institute has been supporting the national and European authorities, Luxembourg companies, and RDI activities to define, implement and evaluate environmental regulations, as well as to bring entities into compliance.

2. CONTRIBUTING TO A SAFE AND HEALTHY ENVIRONMENT USING BIOTECH

Industrial biotechnology offers a new, sustainable approach to the manufacture of chemicals and energy from renewable resources, enabling what is called the circular bioeconomy. Biological natural resources are crucial to our economic system, but they are increasingly overexploited to provide food, materials and energy. Consequently, industrial biotechnology is intrinsically linked to environmental biotechnology, which aims to prevent, halt and reverse the effects of environmental degradation through the appropriate use of biotechnology in symbiosis with other technologies. At LIST, the Sustainable Biotech Innovation Centre is running projects related to the exploration and production of environmentally-friendly bioactive compounds, which have applications in a variety of industries.

In the context of the COVID-19 pandemic, we are also significantly involved in supporting public and private players, in particular through the epidemiological monitoring of the infection of the population with SARS-CoV-2 initiated to support the Luxembourg Government's management of the pandemic.

> « We have been tracking the presence of coronavirus in waste water since the beginning of the COVID-19 pandemic. Our highly sensitive and reliable methodology is able to visualise where, when, and in what concentration SARS-COV-2 is present in Luxembourg. A health benefit has been noted and welcomed by the Government, which since the start of the pandemic has relied on LIST's weekly reports for agile management and decision-making. »
>
> Leslie Ogorzaly,
> environmental microbiology researcher

Success story 1

DETECTING EMERGING VIRAL PATHOGENS USING APTAMERS

In addition to the current SARS-CoV-2 pandemic, a large number of viral epidemics are linked to food- and water-borne viruses. In recent years, we have seen a considerable increase in the development and number of methods for detecting these viruses in different matrices, reflecting a recognition of the increased importance of these viral diseases. We have chosen to study a detection method that uses aptamers. An aptamer is a short, single-stranded nucleic acid (DNA or RNA) capable of adopting a three-dimensional structure which renders it capable of binding to its target with remarkable specificity and affinity. Aptamers are more stable, faster and cheaper to produce, and have a longer shelf life and greater specificity towards their target than the corresponding antibodies.

Leslie Ogorzaly

Currently, no detection method utilising the benefits of aptamers is available on the market. In order to improve infectious viral disease detection we have implemented several projects aimed at developing the aptamers specific to adenoviruses. These projects have resulted in a patent that now opens up new prospects for industrial collaboration. The high potential of aptamer applications on the diagnostic market has been confirmed through market research. This research has enabled us to identify potential future partners for the marketing of our product.

Success story 2

PRODUCING CUSTOM-MADE PLANT MOLECULES ON A PRE-INDUSTRIAL SCALE

Triterpenes are molecules that occur naturally in apples. They are highly interesting in terms of their cosmetic and pharmaceutical applications. Their commercialisation has been seriously hampered by low plant yield and because their chemical synthesis is impossible. To meet this challenge, LIST researchers have developed a synthetic biology-based platform to improve triterpene production, as well as to produce new triterpenes with new or superior bioactivities. As a result, the team has succeeded in modifying the metabolic pathway inside apple cells and developing a series of apple cell lines with a modified triterpene composition. The production of genetically modified cell lines can be scaled up in bioreactors under confined cultivation conditions. This is followed by processes to extract and purify the desired molecules. This platform, an integral part of the Sustainable Biotech Innovation Centre, has great potential to produce custom-made triterpenes to meet industrial needs. In addition, the same strategy can be applied to other plant species to customise the production of various molecules of interest.

Samuel Jourdan

Pamina Weber

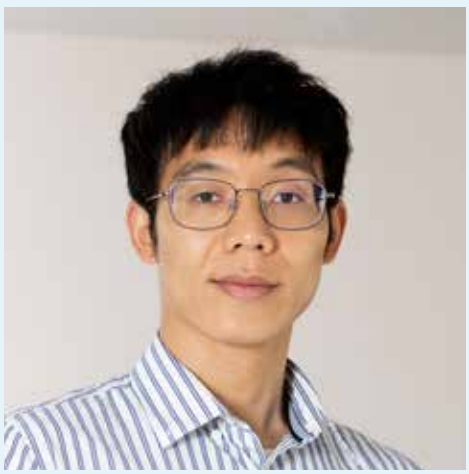
Success story 3

TOWARDS THE CREATION OF AN 'OPEN INNOVATION TEST BED' FOR NANO-PHARMACEUTICALS

In 2021, LIST and 10 partners (research organisations and SMEs from the European biotech field) launched PHOENIX, an innovation project funded by the European Union (EU) Horizon 2020 Framework Programme, aimed at providing services for the development, classification, testing, safety assessment, scaling-up, production and commercialisation of nano-pharmaceuticals on the market, by making them available to SMEs, start-ups, research laboratories and interested users. The 48-month project, coordinated by LIST researcher Tommaso Serchi, has a total budget of 14.45 million euros, with an EU contribution of 11.1 million euros. It aims, in particular, to establish good manufacturing practices (GMP) for large-scale nano-pharmaceutical production . This is a key step in ensuring the transfer of nano-pharmaceutical products from the laboratory to the patient (from the laboratory to the industrial scale). In fact, due to the lack of resources devoted to implementing these GMPs on site, the scaling up and production of these innovative nano-pharmaceutical products remains a challenge for the main players on the European nano-medicine market: start-ups and SMEs.

3. MONITORING, PREDICTING AND PROVIDING FOR THE EFFECTS OF CLIMATE CHANGE

> « In order to obtain physically interpretable, effective and accurate predictions for key environmental variables, I firmly believe that we need to combine new technologies, such as *deep learning*, with an in-depth understanding of sensors, physical processes and environmental sciences. »
>
> Yu Li,
> expert in remote sensing image classification



Today, changes on a global scale are primarily due to mankind's growing demand for natural resources. The Earth system (i.e. the climate and the environment) is now operating in an unprecedented state, where unpredictable and harmful changes are becoming increasingly likely. Many of the technologies available to monitor, predict and provide for the future trajectories of the Earth system suffer from limitations that have hampered the progress made to date, particularly when it comes to studying, for example, the acceleration of the water cycle and its implications for the different components of environmental systems. Whilst new generations of instruments have recently been developed, offering unprecedented temporal and spatial resolutions and transmission rates for environmental monitoring protocols, there is an urgent need for new tools tailored to collecting, transmitting, validating, storing and using the rapidly increasing data flows. The new tools and solutions that we are trying to implement at LIST will, over time, help to guide emergency response operations, balance immediate economic interests and set long-term sustainable development objectives, in an increasingly uncertain and rapidly changing context.

Success story 1

MONITORING FLOODING ON A GLOBAL SCALE USING SATELLITE DATA

On 27 October 2021, the Joint Research Centre (JRC) launched the Global Flood Monitoring (GFM) tool to monitor the flooding taking place across the world as part of the Copernicus Emergency Management Service. This tool, unique in its ability to process all the data received by the Copernicus Sentinel-1 satellites, makes it possible to assist in planning and coordinating emergency responses in the event of floods, or to support international aid to the affected areas. For example, it was already tested this summer to create maps of the flooding that hit Europe in July 2021. LIST researchers Patrick Matgen, Ramona Pelich, Marco Chini, Renaud Hostache and Yu Li, developed one of the three algorithms for extracting the satellite data, the other two were developed by Vienna University of Technology and the German Aerospace Centre. At the global level, GFM produces flood monitoring maps within eight hours of the satellite taking the image, with a spatial resolution of 20m.

Marco Chini

Marine Pallez

Success story 2

IMPROVING THE TARGETED USE OF FUNGICIDES AND PESTICIDES

In precision agriculture, pesticides and other products are used precisely when and where they are needed. For several years, LIST has been working on a series of projects called 'Sentinelle' with the Luxembourg Ministry of Agriculture, Viticulture and Rural Development. This collaboration was extended in 2021, and permitted the launch, in May, of the ShIFT (SeptorIa ForecasT) model: a new software tool enabling certain fungal diseases affecting winter wheat to be predicted. In Northwest and Central Europe, septoria is the most destructive winter wheat disease. It results in spots appearing on wheat leaves. In order to combat this disease in time, farmers need forecasting models to know when to spray fungicide. The ShIFT model, developed by LIST, enables farmers to better monitor this disease and to protect their crops more effectively.

Success story 3

MONITORING TOOLS FOR IMPROVED WATER MANAGEMENT

LIST is working on numerous applied projects funded by the Luxembourg Water Management Authority and the European LIFE Programme, which have led, in 2021, to a portfolio of high-level publications dealing with the use of polar passive samplers to study urgent water management problems. LIST's experts have measured the effectiveness of biological waste water treatment plants at eliminating xenobiotics, put forward a plan for assessing the impact of micropollutants on surface waters, singled out urban sources of biocide emissions, and drawn up coherent assessments of pesticide emissions in agricultural watersheds. This long-term research also led to the patenting of a passive sampler housing, as well as a referenced biological trial, opening up new opportunities for participation in European projects.

Tom Gallé

4. DEVELOPING CLEAN AND SMART ENERGY SYSTEMS

> « Electricity production from photovoltaic systems has increased considerably in the European Union and Luxembourg in recent years. Production is becoming more sustainable, but also less controllable, due to fluctuations in solar radiation. Predicting photovoltaic energy production is therefore essential for network managers and energy suppliers. »
>
> Daniel Koster,
> sustainable energy systems researcher

The growing demand for energy, network congestion, the lack of flexibility in the current electrical power system, new user-centric regulations and future economic models are forcing us to review our traditional energy consumption and find an alternative that complies with the Paris Agreement, European energy policies and the Integrated National Energy and Climate Plan (NECP) for 2021-2030.

In 2019, the Luxembourg Government took the decision to reduce its greenhouse gas emissions by 55% (compared to the benchmark year 2005) and to increase the share of renewable energies to 25% by 2030, in order to finally achieve carbon neutrality and 100% renewable electricity by 2050.

LIST fully intends to contribute to meeting this challenge over the coming years, by developing new energy systems for society and industry, in which the production, infrastructure and consumption of clean energy are intelligently integrated and exploited (in a fraction of a second) by digital platforms and advanced energy processing technologies.

Success story 1

BETTER INTEGRATION OF PHOTOVOLTAIC ELECTRICITY INTO NETWORKS AND MARKETS

As part of the COMBI-CAST research project, LIST, in collaboration with Electris, the distribution network manager and electricity provider for the Mersch region (L), has developed a new model combining three complementary methods in order to forecast photovoltaic power in a given region in the very short term, using self-learning algorithms. Such forecasting will allow stakeholders to better predict the net charge, as well as to reduce costs. In the long term, this will increase the opportunities for the direct sale of photovoltaic electricity. In addition, network managers will be able to rely on a future smart network enabling them to better estimate the flexibility needs of their networks and the optimal operation of flexibility options, such as storage or demand management.

Pedro Rodriguez

Florin Capitanescu

Success story 2

A LABORATORY FOR REAL-TIME EXPERIMENTS AND SIMULATIONS

In 2021, we set up a laboratory capable of performing real-time simulations at the same speed as actual executions: a microsecond in the simulation field is executed in a microsecond in real life. This is particularly useful for evaluating the interaction of a real physical system with a virtual system simulated on a real-time computer. We call this integration of hardware into the simulation process hardware-in-the-loop (HIL).

Our laboratory can be used to evaluate the interaction of any generic physical system (mechanisms, reactors, sensors, etc.) with any generic virtual environment (operating scenarios, virtual test banks, disturbances, etc.). Due to its ability to evaluate the performance of real systems under generic and controllable operating conditions, with full monitoring of all signals, this type of laboratory is widely used for developing and testing systems in the aerospace, automotive, bioengineering and energy sectors, because it allows costs, time periods and risks to be reduced through the early detection of development errors in R&D projects.

Success story 3

INTEGRATING MORE RENEWABLE ENERGY INTO THE ELECTRIC POWER SYSTEM

Distributed energy resources systems (DER) are small-scale electricity generation technologies, such as solar panels or wind turbines that provide an alternative or addition to traditional electric power. While industry and households are increasingly turning to DER to complement their energy supply, national or regional networks are not always designed to cope with renewable and decentralised energy production. Nowadays, energy companies must manage, monitor and maintain hundreds of thousands of small assets, and must strive to implement smart and predictive technologies, such as artificial intelligence, machine learning and digital twins to turn this mass of data into intelligible information.

As part of the TESTIFY project, LIST is putting forward a new approach to the secure management of the entire electricity grid, making optimal use of the flexibility of distributed energy resources, and primarily renewable energy sources, such as wind and solar. The project addresses three fundamental issues in an integrated manner: (i) how to quantify the DER flexibility available, (ii) how to integrate this flexibility into network operator security management, and (iii) how to formulate and resolve these issues in a mathematically coherent and effective manner. The project will make it possible to integrate more renewable energy into the electric power system in a cost-effective manner, while maintaining system safety.

5. DESIGNING RELIABLE AND QUALITATIVE SERVICE SYSTEMS

LIST takes on the challenge of quality in business service systems Reliability, data security, compliance with national and international regulations and standards, user interface, etc.: all of these service features are based not only on the attributes of the computer infrastructure used, but also on aspects related to the quality of the applications deployed on these infrastructures, as well as on the organisational dimensions and human skills needed to provide the services.

Furthermore, in an increasingly interconnected world, in which services provided by one entity will themselves be reliant on services provided by others, the concept of service quality should be regarded as a systemic approach applied to a global service ecosystem, and not merely to the level of a single isolated service provider.

> « Many risk management tools exist at present, however no integrated platform allows regulators and regulated companies to come together, several regulations to be addressed, sector libraries to be shared and sector risk data to be analysed. The platform we are working on will contain more information and recommendations, and will give regulators access to a complete overview of the ecosystem of the sectors and stakeholders concerned, for greater security and protection of the services in question. »
>
> Nicolas Mayer,
> reliable data systems researcher

Success story 1

A REGULATORY PLATFORM FOR TELECOMS AND ESSENTIAL SERVICES OPERATORS

From telecoms to energy, and from the healthcare sector to transportation, each company is subject to regulations that shape its business and aim to prevent all risks. While some cover, for example, environmental or staff safety, information security plays an increasingly important role in an ever more digital world. To ensure they comply with these regulations, companies must not only apply best practices, but also manage their risks, submit analyses and report incidents. This is a time-consuming and complex exercise for which there is often no clear methodology, useful knowledge bases, or centralised tool.

This is where LIST comes in. In close collaboration with the Luxembourg Regulatory Institute (ILR) for a decade, and with the Belgian Institute for Postal Services and Telecommunications (BIPT), LIST researchers have developed a prototype and then created a regulation platform called SERIMA (SEcurity RIsk MAnagement). Designed by LIST and the ILR, this platform enables operators to carry out risk assessments, in the telecoms sector in particular, and in the near future for all essential service operators. The ILR interacts with the so-called regulated entities via a single interface using this platform. Thus, each company in question can receive notifications from the regulator, use a common methodology for carrying out risk assessments and report incidents in accordance with the regulations in force. The next features for systemic risk analysis are being designed and are expected to allow a new level to be attained that is unique in Europe.

Sébastien Pineau

Philippe Valoggia

Success story 2

DETECTING DARK PATTERNS ONLINE

In 2021, LIST launched the DECEPTICON project with the University of Luxembourg, a project that gets to grips with what are commonly referred to as Dark Patterns. In other words this is information which can mislead us, manipulate us and ultimately motivate us to make the wrong decisions, without realising the consequences. One of the major challenges of the project is to be able to identify these Dark Patterns, whatever form they take. The idea is firstly to understand that a phrase is written in a suspicious or erroneous manner, and then to identify the target, as the impact will vary between users. The project focuses on four objectives: creating an online database in order to share a whole set of knowledge about Dark Patterns; distinguishing between online manipulation and deception; gathering evidence about the effects of Dark Patterns on user behaviour; and finally developing procedures and tools to assess the presence of Dark Patterns in online services.

Success story 3

FACILITATING 5G ROLL-OUT AND SUSTAINABILITY

LIST is at the forefront of research into and innovation for new mobile communication networks, with several parallel projects in relation to the roll-out and adoption of 5G, with its future development and 6G in their sights.

Representative of this innovation is the 5G-EMIT project, co-funded by the Luxembourg Department of Media, Connectivity and Digital Policy (SMC). The objective of this project is to facilitate the roll-out, compliance and sustainability of 5G in Luxembourg by proposing new models and technologies, taking into account the limits for the electromagnetic fields (EMF) produced by 5G installations, whose technologies are very different from previous generations. A national public observatory, displaying real-time measurements taken in Luxembourg, as well as a network planning solution recommending optimal roll-out strategies, are being developed. In addition, this project aims to use the Grand Duchy model as a test bank that can potentially be reproduced in other countries in the future.

Raising awareness among the general public and companies is also essential in facilitating the adoption of new technologies. Thus, LIST has set up and launched a unique awareness-raising platform called 5G-PLANET, also co-funded by the SMC. The idea of this platform is to introduce and explain the technologies behind 5G, using mobility applications as an example and creating a series of demonstrators for these, all accessible to as many people as possible from summer 2022.

Many other cooperative projects are in progress, whether in the areas of security, optimisation or peripheral computing. 2021 was marked, for example, by the launch of the 5G-INSIGHT project, a cooperation between Luxembourg and France on the safety of vehicle networks which rely on 5G in border areas, which makes Luxembourg the ideal candidate.

Sébastien Faye

6. EXPLOITING DATA FOR THE BENEFIT OF THE ECONOMY AND SOCIETY

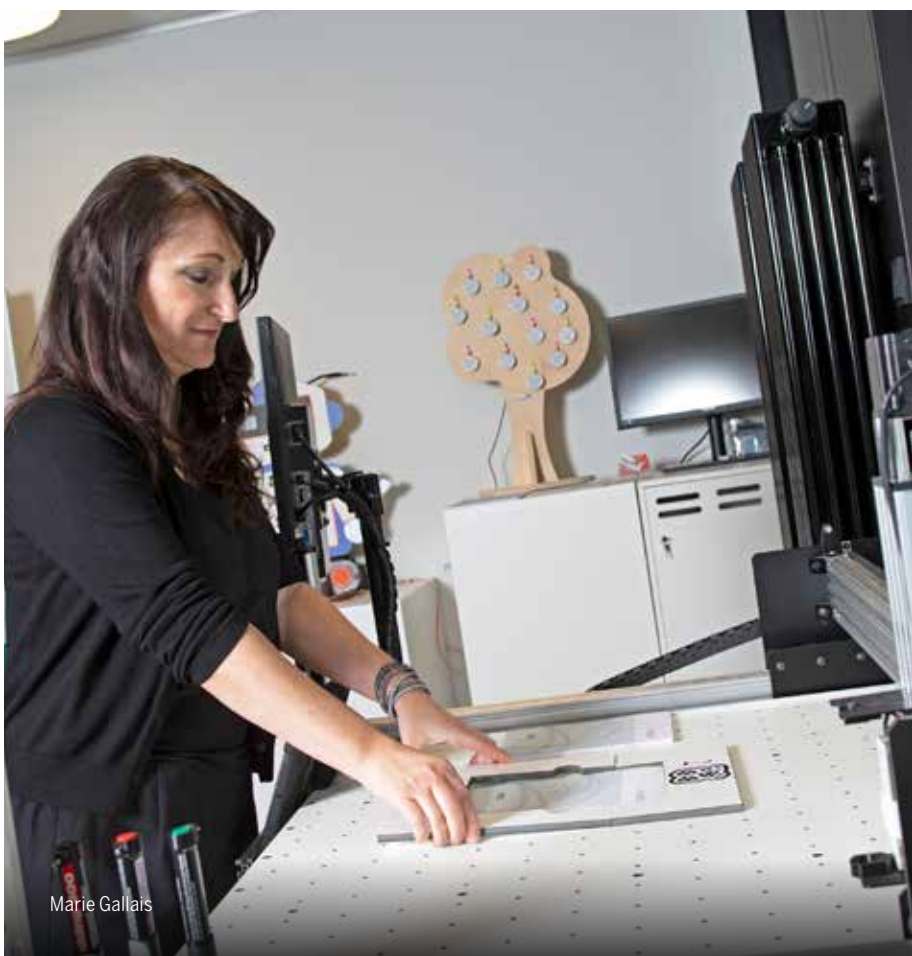
Our world produces data at an unprecedented rate. Thanks to new approaches in data science, this massive amount of data can be exploited for the benefit of the economy and society. However, humans must be kept in the loop of this new paradigm. Therefore, we are focussing on how to imagine, implement and evaluate different types of data analysis methods and tools that people can understand and interact with. User experience, augmented reality and visualisation are therefore key skills in which we also have robust experience in order to maintain the link between data, models and people.

> « With our *in situ* training solution, users gain confidence directly on their workstation, and errors and dangers can be avoided through system feedback. »
>
> Marie Gallais,
> human modelling researcher

Success story 1

AN INNOVATIVE *IN SITU* LEARNING ASSISTANT FOR INDUSTRY WITH NO-NAIL BOXES

Increasing production is a major issue in the world of industry. When production rises, we need more staff, including, for example, external employees who are not necessarily familiar with the machines on which they have to work. Therefore, they must be trained very quickly. This major issue can be resolved thanks to the *in situ* learning assistant developed by LIST with No-Nail Boxes, a Wiltz-based company that produces plywood folding boxes for a wide variety of industries. This innovative project lends a new dimension to Industry 4.0 through the creation of an *in situ* learning assistant for computer numerical control (CNC) machines.



Marie Gallais

Olivier Parisot

Success story 2

HIGH-QUALITY, NOISE-FREE ASTRONOMICAL IMAGES

Today, Electronically Assisted Astronomy is widely used to observe deep-sky objects, such as nebulae or galaxies. By capturing images using a camera connected to an optical instrument, this approach aims to display enhanced views of the target objects in near real-time on a screen, by running a minimal image processing phase. Observing the night sky therefore becomes more accessible to the general public, and in particular to people who find it difficult to use a telescope directly, because of poor visual sharpness for example.

In this context and as part of the MILAN (MachIne Learning for AstroNomy) project, LIST and VAONIS, a French company specialising in the development and sale of a new generation of automatic and smart telescopes, are jointly exploring how recent Deep Learning approaches can help to produce clear and realistic images, even when observation conditions are not ideal. These innovative features should help the company to continue to raise its competitiveness and its unique positioning on the market.

Success story 3

CONTRIBUTING TO THE EUROPEAN VISUALISATION RESEARCH LANDSCAPE

Network and graph data is omnipresent in science, engineering and business. How to analyse and visualise large graphs often remains a challenge. This is why a team of LIST visualisation researchers has published a comprehensive book on visualising multilayer networks together with international colleagues. Entitled *Visual Analysis of Multilayer Networks*, this book is the work of Fintan Mc Gee, with contributions from Mohammad Ghoniem and Benoît Otjacques, three LIST data visualisation researchers. By identifying research opportunities and examining the challenges to be tackled in terms of visualising multilayer networks, potential solutions and future research directions to resolve these, this book shows that LIST is regarded as a valuable contributor to the European visualisation research landscape.

Fintan McGee

7. DESIGNING EFFECTIVE AND SUSTAINABLE COMPOSITE MATERIALS

LIST aims to develop the next generation of composite materials, focusing on their sustainability and recycling, as well as on unparalleled performance in terms of weight and mechanical properties, while optimising the key element of composite materials: fibre-matrix interfaces. The entire development chain is covered, from the engineering of the materials to their manufacture, via design optimisation and functional testing. The combination of modelling and experimentation makes it possible to improve informed decision-making resulting in more effective and sustainable composite materials.

> « We have paved the way for the sustainable design of composite materials by combining computer modelling and simulation, based on physics and data, with the generation, reconstruction and analysis of the microstructure of materials. »
>
> Claus Bayreuther,
> head of the Composite Modelling group

Success story 1

PREDICTING THE PERFORMANCE AND FAILURES OF VARIABLE STIFFNESS MATERIALS

Variable Stiffness Composites (*VSC*) are essential for light-weight and high-performance applications, such as aerospace. As part of a research project led by Gaetano Giunta, LIST aims to develop a theoretical framework and a multiscale modelling strategy capable of determining both the best configuration for a VSC structure and taking account of the main manufacturing requirements, as well as the imperfections caused by the processes, from the design phase.

Therefore, the team is working on developing a modelling strategy enabling the mechanical performance of these composites to be predicted, while taking into account failure mechanisms on the mesoscopic scale, i.e. the intermediate scale, between the atomic and the molecular.

Gaetano Giunta

Frédéric Addiego

Success story 2

A SHARED LABORATORY PRODUCING ULTRA-LIGHT STRUCTURES FOR THE SPACE SECTOR

In the space sector, weight is expensive. The heavier a product that needs to be transported into space is, the higher the cost. The current estimate is about 5,000 to 10,000 euros per kilogram, meaning that any loss of weight is financially advantageous for companies that send satellites into space.

In 2021, LIST entered into a new partnership with the Luxembourg company Gradel, in order to research and produce ultra-lightweight structures for the aviation and space industry using continuous carbon fibre reinforced polymers to create 3D structures. Parts will be produced for three major European satellite manufacturers: Thales Alenia Space (France), Airbus Defence and Space (France) and OHB (Germany).

Success story 3

DESIGNING THE TYRES OF THE FUTURE: ANOTHER STEP TOWARDS SUSTAINABLE MOBILITY

Within the framework of the Goodyear-LIST partnership, the largest public-private RDI partnership to date in Luxembourg, the CORUCOMP project aims to study the mechanisms taking place at the interface between the rubber matrix and the cable/fibre (which acts as a reinforcement agent for the tyre). In order to improve adhesion between the cords and the rubber, the cords are coated using the processing conditions and immersion solution developed by Goodyear. Until now, the changes to the cord-rubber interface that take place during the tyre vulcanisation process and subsequently during dynamic fatigue testing were not fully understood. Consequently, LIST researchers decided to study the link between the structural changes and the phenomenological properties resulting from thermal ageing and dynamic fatigue. Demonstrating interaction between the tyre cord and the rubber matrix is of paramount interest for the next generation of tyres.

8. CREATING MATERIALS WITH UNIQUE PROPERTIES USING FUNCTIONAL POLYMERS

Functional polymers are macromolecules with unique properties. They are generally inexpensive and easy to synthesise. At LIST, we are working on the synthesis, formulation and processing of the polymers in order to obtain specific property enhancements and multi-functionality through experimental and digital physics-based approaches, including molecular modelling.
Our research is based on two axes: the production of sustainable polymer materials, and the chemistry and physics of smart and reactive polymers.

« We are working on energy storage, and in particular on the future generation of polymer electrolyte-based supercapacitors. Energy, in fact, lies at the core of LIST 's strategy: whether it is its production, its recovery, its optimisation, or its storage. »

Stephan Westermann,
head of the Functional Polymers unit

Success story 1

A NEW GENERATION OF PLASTICS OF RENEWABLE ORIGIN

In recent decades, a new generation of plastics called polybenzoxazines has emerged from academia and crossed over into industry. These materials have become promising and sustainable alternatives to the existing resins used for the production, for example, of high-performance materials in aircraft or space rockets. Unlike resins, polybenzoxazines do not produce toxic compounds and can be synthesised from components of biological origin, instead of petroleum products. While research on polybenzoxazines is widespread in China and the United States, this same is not true of Europe, where only six European institutes are currently working on these polymers. As an active member of this network, LIST has devoted several research projects to this subject.

In 2021, researcher Pierre Verge and his colleagues continued to build LIST's reputation for cutting-edge benzoxazine research. Collaboration has been initiated with Gradel SARL to develop bio-sourced benzoxazine vitrimers and to adapt these to a robotic filament winding process. The team also organised the fourth International Symposium on Polybenzoxazines, which attracted high-level scientists from all over the world, and provided an excellent forum for new interactions in this fascinating field of research.

Pierre Verge

Muhammad Yasar Razzaq

Success story 2

4D PRINTING: A NEW DIMENSION FOR POLYMERS

4D printing is the ability to print an object that, after a predetermined time, can change shape due to the effect of an external factor such as light, heat, humidity, vibration, etc. It has many applications, particularly in the medical field, as well as in the fields of construction, industry and fashion. Polymers are at the forefront of this breakthrough as these futuristic materials will inevitably be composites. It is specifically the union of polymers with other materials, sometimes natural, such as wood cellulose, that gives objects their ability to change shape or react to a stimulus.

LIST is working on shape-memory polymers in particular, a family of polymers that is compatible with 4D printing. These are materials that are already well-known and whose properties have been modified to give them a dynamic memory effect. Once stimulated (heat, electricity, light, etc.), these polymers are able to shift from one shape to another.

In 2021, LIST also continued its work on integrated detection technologies in 3D-printed polymers as part of an industrial collaboration with the Guala Closures group.

Success story 3

WELCOMING OUR FIRST FULBRIGHT STUDENT

In 2021, we welcomed our first student supported by the Fulbright Program for American students: Samantha Mannes, a student from the group of Prof. Brett Compton of the University of Tennessee in Knoxville, whose specific expertise is in the field of 3D printing by direct-ink-writing. The Fulbright Program, founded in 1946, is one of the world's most famous and prestigious grants. We anticipate a significant increase in LIST's capabilities in the additive manufacture of polymers, and to consolidate a robust basis for further developments in this field. In addition, such agreements help to raise LIST's international standing and open the door to future collaboration with a leading group in this field.

Samantha Maness

9. EXPLORING THE MICROSCOPIC WORLD TO DEVELOP MATERIALS WITH EXTRAORDINARY PROPERTIES

The detection of gas or (bio)molecules, mechanical and vibrational strain, and the recovery, storage and use of energy are just a few examples of extraordinary properties made possible by nanotechnologies. LIST is working on the technological development of materials controlled at the nanometric level, which, combined with an innovative chemistry of these same materials, makes it possible to demonstrate properties that are all the more remarkable as they are incorporated into functional devices. In addition, the engineering of specific nano-objects paves the way for disruptive medical applications (probes, bone regeneration, anti-bacterial coatings, etc.) and complex high-performance nanocomposites.

> « Developments in the field of nanomaterials are needed for new applications related to, among others, catalysing and storing energy, ferroelectricity, and the ultra-sensitive detection of the molecules or biomolecules needed to implement personalised medicine. »
>
> César Pascual García,
> researcher and European Innovation Council (EIC) Ambassador

Success story 1

WORKING ON THE NEXT GENERATION OF COPPER FOIL

In 2021, Circuit Foil and LIST signed a partnership worth 18 million euros to work on the next generation of copper foil: the largest public-private partnership ever signed between a medium-sized Luxembourg company and a public research centre, supported by the Luxembourg Ministry of the Economy, the National Research Fund and the Luxembourg Ministry of Higher Education and Research. The markets covered by the LIST/Circuit Foil partnership include 5G and 6G communications, composite copper materials for aeronautics and lithium-ion batteries.

Demand for copper is expected to rise over the coming years. By 2030, demand will have increased by 2.5 times in volume, which clearly illustrates the pressure that will be placed on copper as a resource. Major research investments in the technologies and manufacture of advanced copper foil are essential to capture the fantastic prospects of this market to serve the digitisation and sustainable transformation of our society.

Anthony Valero & Julien Barbe

Sivashankar Krishnamoorthy

Success story 2

DETECTING HEALTH PROBLEMS USING NANOTECHNOLOGY

In order to detect, monitor and treat a patient's health problems, high-performance biological devices, based on a delicate optimisation of surface properties, are needed. These are, for example, biosensors or bio implants. In view of the significant progress made over the past decade, surface properties must now be optimised on the level of the molecules themselves. The NANOSENS project, led by Sivashankar Krishnamoorthy and his team, aims to develop a sophisticated biosensing product enabling the provision of sensitive, quantitative and real-time measurements of the interaction of a biological environment consisting of biomolecules or biological cells with a nanostructured interface. The project should make it possible to improve the performance of medical technologies in the field of diagnosing, monitoring and treating diseases or patients' health problems.

Success story 3

FERROIC MATERIALS AT THE HEART OF INTER-INSTITUTIONAL RESEARCH

Multifunctional ferroic materials display many physical properties such as magnetism, ferroelasticity or ferroelectricity, for which they are considered to be 'smart' materials. In 2021, the University of Luxembourg and LIST established the first inter-institutional research group (IRG) in Luxembourg: *Multifunctional Ferroic Materials*. Through the studies that the IRG will conduct into these materials, scientists seek to understand these physical properties in order to better control them. The interactions, called coupling, between multiple properties constitute the basis of modern transducers, devices that convert energy from one form into another.

The IRG is based on a common-interest research programme that focuses on lead-free ferroic materials. These are more environmentally-friendly than the current industrial lead-based materials, and on the effect of light on these multifunctional materials.

Kevin Menguelti & Renaud Leturcq

Success story 4

MINIATURISED AND EXTREMELY SENSITIVE GAS SENSORS

The ability to manufacture, manipulate and assemble materials on the nanoscale means that unprecedented surfaces and functional devices can be developed, utilising the specific properties of nanometric systems. As part of the CLASMARTS project, in summer 2021, LIST delivered a prototype enabling the deposition of thin nanostructured layers assembled in clusters on appropriate substrates according to source parameters. The CLASMARTS prototype will be dedicated to studying nanoporous films and their electrical transport properties. The project should pave the way for the development of highly miniaturised gas sensors, equipped with better sensitivity and response dynamics, and a lower operating temperature.

Emmanuel Defay, Alfredo Blazquez Martinez, Nagamalleswara Rao Alluri, Sebastjan Glinsek, Veronika Kovavova, Pranab Biswas (Uni.lu), Georgy Gordeev (Uni.lu) & Robert Oliva Vidal (Uni.lu)

10. DESIGNING STATE-OF-THE-ART SCIENTIFIC INSTRUMENTATION

> « We focus on platforms comprised of modular building blocks, including both material synthesis and characterisation steps, with the aim of setting up automated synthesis infrastructures capable of self-optimisation based on pre-defined target parameters. »
>
> Tom Wirtz,
> head of the Scientific Instrumentation unit

Speed, spatial resolution, atomic sensitivity, and complex and dynamic data analysis We enjoy meeting the challenges presented by scientific instrumentation and pushing the boundaries of this very special type of engineering. Our aim is to develop new instruments, processes and methodologies in the fields of plasma science and technology, thin-layer processing and nanoanalysis.

Success story 1

TOWARDS STATE-OF-THE-ART LASER INSTRUMENTATION

In 2021, researcher Alexandros Gerakis received a 2-million-euro ATTRACT grant from the NRF for his FRAGOLA project (FRequency AGile Optical Lattices). The aim of the project is to deliver a complete non-destructive laser diagnostic solution for ionised mediums. This will be the first demonstration of its kind with such capacities, entailing an in-depth understanding of the interaction between light and matter.

High-performance laser-based techniques offer many advantages, such as species selectivity and more accurate measurements of temperature, density, flow velocity, etc.

This ATTRACT research programme recognises the strategic interest in investing in the most advanced material diagnostic and manipulation technologies using cutting-edge laser instruments. These are essential skills for LIST, which will be able to accelerate, over the next five years, its knowledge of the smart control of synthesis processes and quantum dot manipulation.

Alexandros Gerakis

© FNR / Giuseppe Bengasi

Success story 2

AN EXCEPTIONAL PHD THESIS

Faced with the current global energy and environmental crisis, one of the avenues on which LIST is working is the development of a new class of materials for the clean and efficient production of hydrogen from porphyrins. Porphyrins are very common chemical compounds that enable life on Earth: they form the basis for photosynthesis in plants and respiration in humans. Our objective is to try to copy nature and develop porphyrin-based polymers and to thus enable other reactions, such as the production of clean hydrogen.

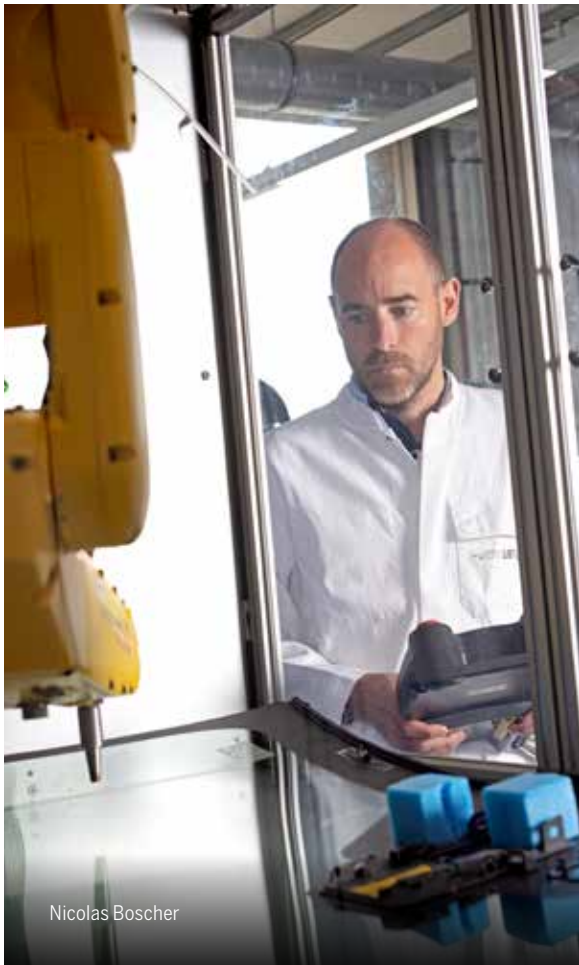
Researcher Giuseppe Bengasi won the NRF 2021 Awards for his PhD thesis. During his PhD, Giuseppe Bengasi and his research team invented a unique method enabling the synthesis and simultaneous deposition of porphyrin polymers as thin films. The process can be easily transposed onto an industrial scale and is suitable for coating substrates, such as plastic and paper. The method co-developed by Giuseppe Bengasi enables the the optical and electronic properties of porphyrin polymers to be engineered and paves the way for their use in flexible electronics and catalysis. One of the possible applications is the production of clean hydrogen. If this breakthrough is achieved, this technology could support a new economy, built not on fossil fuels but on hydrogen.

Antje Biesemeier & Olivier De Castro

Success story 3

THE NEW NPSCOPE INSTRUMENT IS OPERATIONAL

Nanoparticles can pose risks to human health, the environment and safety. It is therefore crucial to identify, study and limit these risks. In order to do this, we need to carry out an adequate physicochemical characterisation of these nanoparticles. This characterisation will be rendered much easier by the new npSCOPE instrument, which was developed by an international team of researchers coordinated by LIST. In 2021, after 4.5 years of work undertaken by nine partners from six European countries, the project was successfully completed. The npSCOPE instrument is now fully operational in LIST's laboratories and provides an unprecedented view of nanoparticles, opening up new possibilities in nanotoxicology.


Nicolas Boscher

Success story 4

ANTI-FOG FILMS FOR WINDSCREENS

Within the framework of the DOMUS project, funded by the European Commission's Horizon 2020 Framework Programme, LIST has successfully developed an atmospheric plasma-assisted deposition method for the rapid and low-temperature preparation of thin anti-fog films on windscreens. The method and formulation of the selected thin layer were applied to a windscreen mounted on a Toyota car and tested in a wind tunnel. Mission accomplished for LIST: the coated portion of the windscreen showed a significant reduction in fogging.

11. MAKING A HUMAN PRESENCE IN SPACE DURABLE USING SPACE RESOURCES

Space resources will be key to the future of space exploration. Being able to use them is a crucial step in making a human presence in space viable. This will also open up new prospects, particularly in terms of economic models. The European Space Resources Innovation Centre (ESRIC), funded by LIST and the Luxembourg Space Agency (LSA) with the European Space Agency (ESA) as a strategic partner, was established in August 2020. In addition to developing research activities across the entire space resources value chain, the centre supports the commercial initiatives of established stakeholders and start-ups, enables the transfer of technology between the space and non-space industries, and encourages public-private partnerships and new initiatives in the field of space resources.

> « In the context of the use of space resources, the issues of sustainability, the circular economy, environmental conservation and the processing of waste are key. While space resources offer a means to explore the Moon and the solar system in a sustainable way, the space resources field can also serve to stimulate innovation on Earth and to find new ways of meeting global challenges. »
>
> Abigail Calzada Diaz,
> lunar resources researcher

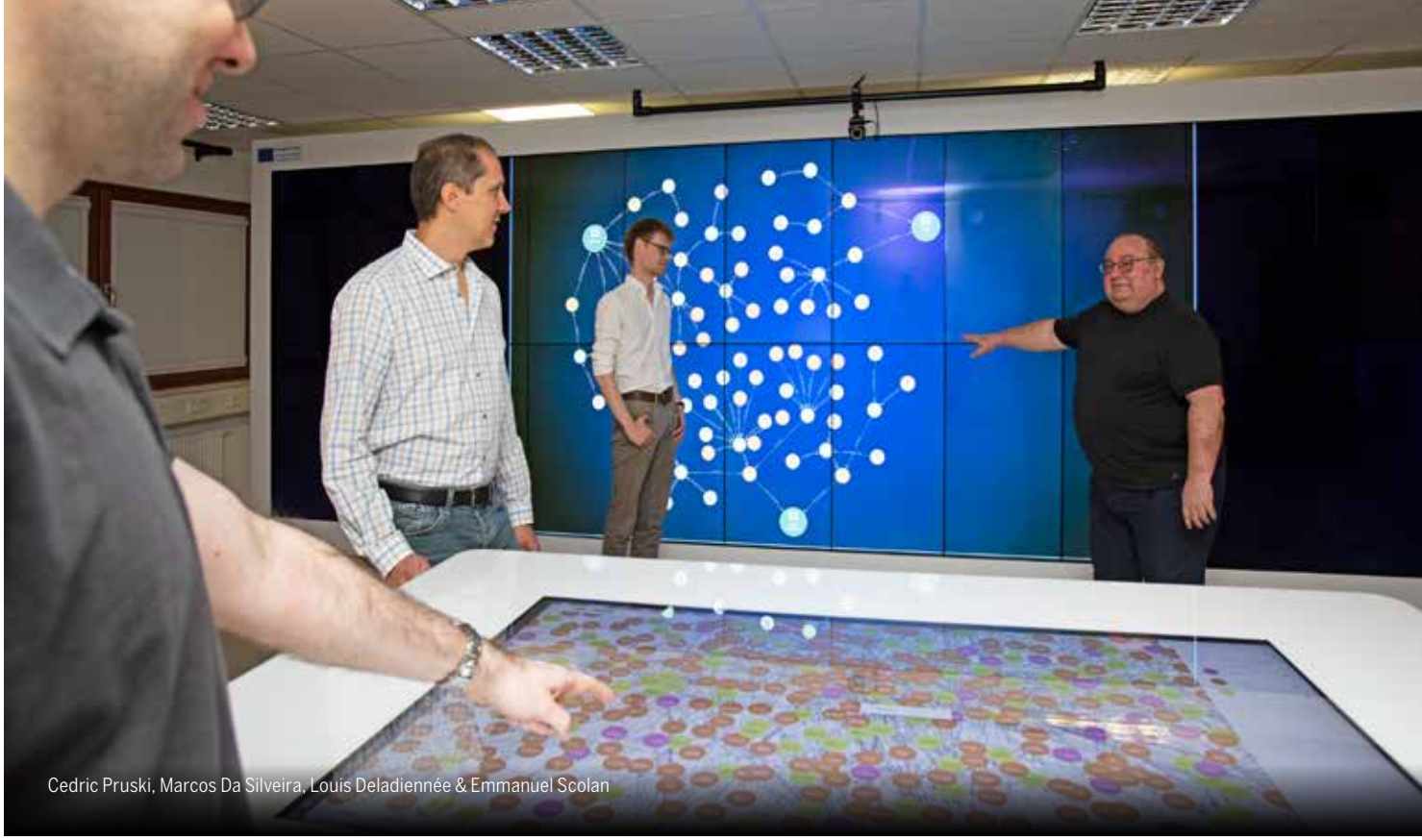
Success story 1

SUPPORTING SPACE RESOURCE START-UPS

In 2021, ESRIC launched the Startup Support Programme (SSP): the world's first ever incubator programme dedicated to the topic of space resources. In partnership with the European Space Agency (ESA), the Luxembourg Space Agency (LSA), LIST and Technoport (Luxembourg's main technological incubator), the programme aims to support space resource sector start-ups in their early phase, to develop their business models, attract their first customers and secure their first investments.

The three-month pre-incubation phase allows five selected start-ups to validate technical concepts and align these with market opportunities. They will benefit from support in-kind, for both the technical and commercial aspects of their project. After this first three-month phase, the best project will be selected for a two-year incubation phase, during which the start-up will be able to establish its technical value proposal and further develop its business model. Additional technical and commercial support will be provided during the incubation phase, and funding in the form of a non-refundable grant of up to 200,000 euros will be allocated to the start-up.

Lari Cujko



Cedric Pruski, Marcos Da Silveira, Louis Deladiennée & Emmanuel Scolan

Success story 2

AMBITIOUS PARTNERSHIPS FOR A FUTURE SPACE ECONOMY

ESRIC aims to become the internationally-recognised centre of expertise for the scientific, technical, commercial and economic factors related to the use of space resources for human and robotic exploration, as well as for a future space economy. By partnering with public and private international players in this field, we want to create a hub of excellence for space resources in Europe. The two collaborations launched in 2021, with Air Liquide and the National Centre for Space Studies (CNES) on the one hand, and with Airbus Defence and Space on the other, are very promising for the future of the sector.

On 7 July 2021, CNES, the Luxembourg Space Agency (LSA), the European Space Resources Innovation Centre (ESRIC) and Air Liquide signed a Letter of Intent confirming their wish to collaborate on developing research and technology activities (R&T). The objective is to form, by 2022, joint teams that will work on concrete research projects aimed at developing key technologies for the production and *in situ* use of the various gases needed for more sustainable space exploration.

On 26 October 2021, ESRIC signed a memorandum of understanding with Airbus to collaborate on lunar resource extraction technologies. This will lead to the development of key technologies for the use of *in situ* resources (ISRU), in the fields of resource processing and materials recycling. As part of this strategic partnership, Airbus and ESRIC will continue to develop technologies enabling the production of oxygen on the moon, the production of raw materials from regolith and metal recycling, with the aim of producing a demonstrator of a future ISRU pilot plant. The ability to use local resources will be a key element in maintaining a sustainable robotic and human presence on the moon.

Success story 3

A KNOWLEDGE-SHARING PLATFORM FOR THE SPACE RESOURCES COMMUNITY

In 2021, ESRIC launched a project to create a knowledge-sharing platform for the space resources community. This platform is expected to respond to community motivations identified in a survey conducted between April and July 2021. One of the main sector expectations: having access to a centralised and easy-to-use knowledge base. Therefore, a team of LIST engineers has started working on a data visualisation tool integrating scientific publications, news, patents, books, press articles, legislative documents and social media posts. ESRIC's knowledge-sharing platform should be of great interest to researchers, whilst also highlighting business opportunities for companies.

esric

powered by LSA, ESA & LIST

OUR NEW RESEARCH INFRASTRUCTURES

FOCUS ON KEY INFRASTRUCTURE AREAS

Our state-of-the-art infrastructure is one of LIST's main assets: The diversity and quality of the equipment represents real added value for our researchers, as well as for our partners, who can pool their equipment in order to reduce costs and speed up their innovation agendas.

In 2021, LIST continued its work to expand and reorganise research and technology infrastructures:

- LIST spent several months setting up the new Aile Nord, Aile Sud building located in Belval, in collaboration with the Belval Fund. At the beginning of September, an initial group of around twenty employees moved into the centre and installed their laboratories. This five-storey building has been renamed the House of Materials and is intended to house the entire LIST Materials Department, as well as the European Space Resources Innovation Centre (ESRIC) by 2024. The surface area of the building presents a real asset for the LIST teams, and opens up opportunities for growth, the acquisition of new machines and potential new partnerships.
- The Sustainable Biotech Innovation Centre, an open innovation facility focusing on the development of bio-based products and processes of industrial interest, new biorefining concepts, and new technologies for the detection and treatment of environmental pollution, has continued to grow through the implementation of plans to expand its infrastructure in Hautcharage. LIST is expected to host pilot lines there in 2022. This infrastructure will enable LIST to better serve its industrial partners by allowing them to test innovative technologies in a pre-commercial production environment.

- The Artificial Intelligence & Data Analytics (AIDA Lab) technological infrastructure has been put into operation. A product of the ERDF DAP project, it provides a cutting-edge environment for accelerating research and innovation in Artificial Intelligence and data analysis for LIST and its external partners. It is based on hybrid and agnostic technologies combining both proprietary and open source solutions, and is based on the Visualisation Wall (Viswall) as well as MeluXina's high performance computing infrastructure (HPC).
- The ESRIC laboratories have been upgraded through the acquisition of two prototypes, provided by the European Space Agency (ESA), enabling critical resources, such as water, oxygen or metals, to be extracted from regolith. The aim is to explore physicochemical processes in order to understand their mechanisms, optimise them and make recommendations for their use during a future ESA mission.

Louis Deladiennée & Luc Vandenabeele

Dennis Harries & Emmanuel Scolan

OUR COLLABORATIONS

TESTIMONIALS

« We have several collaborative projects running with LIST, for example, we are trying to ascertain the age of water in rivers, and we also compile data and publish a report after each flood or drought. I really like working with LIST. They have very interesting ideas and projects. I think we can work together for a long time. »

Christine Bastian,
Head of the Hydrology Department at the Water Management Authority

« LIST is an excellent partner who shares our passion for science. We have the same project management structures, which we created together. Therefore, we have the same goal, the same timetable and the same pace for reviewing our progress. This has helped us to stay focused and deliver on time. »

Romain Hansen,
Director of Innovation Technology at Goodyear

« Innovation forms the cornerstone of our business. LIST arrived at No Nail Boxes with a completely different thought process: LIST has a research-driven way of thinking, which was new to us. They asked good questions, proposed an interesting approach... we weren't used to working in this way. »

Stephane Guirsch,
Technical Manager at No Nail Boxes

OUR COLLABORATION MODELS

BILATERAL RESEARCH

If you need specific expertise or would like to use the best research infrastructures, you would do well to enter into a bilateral collaboration with LIST. We offer you four types of bilateral collaboration:

SERVICE AGREEMENT

For results that help you to achieve your innovation aims quickly: we share our highly-qualified experts with your company.

The service agreement may also cover the provision of our infrastructure. You can access cutting-edge laboratories, equipment and methods to meet a specific need. Therefore, you can make optimal use of our technological expertise, particularly in the fields of testing, measurement, analytics, innovation management, and method and software development. We offer an extremely wide range of standardised and customised services.

As part of the service agreement, you bear all the costs but obtain quick results in return.

COLLABORATIVE PROJECT

This is a bilateral agreement in which LIST invests with you. We share our resources, expertise and infrastructure with our partner, but for a collaborative project, innovation costs are shared, and intellectual property is assigned to clearly identified contributors.

STRATEGIC PARTNERSHIP

For outstanding and sustainable results that require various skills: we jointly define a framework agreement for a medium or long-term strategic R&D partnership based on your innovation roadmap. This is a bilateral agreement that may involve the recruitment of PhD students dedicated to your research project. Intellectual property is assigned to the contributors to the invention.

"SPIN-OFF" OR "LICENSING"

Technology transfer is an important part of the value creation process. It involves transferring technologies to the market by creating new companies (spin-offs) or by granting licences to existing companies. This is how LIST innovations are transformed into products, economic activity and high-quality jobs. The agreement may take the form of a capital interest, royalty sharing or licence purchase.

RESEARCH WITH MULTIPLE PARTNERS: LIST'S PARTNER PROGRAMMES

LIST facilitates synergies between partners by bringing them together to share the benefits of its skills, talents and infrastructure. This collaboration model forms the cornerstone of LIST's innovation centres. The sharing of expertise, research and risks between partners throughout the value chain makes it possible to reduce costs for all parties concerned. All partners, as well as their own research teams, settle in at LIST and benefit from the unique advantages offered by LIST: an open research and technology infrastructure and first-rate talents.

How does it work? We implement a strategic programme. This is a multilateral agreement that involves the sharing of intellectual property between the various project partners.

SHARING OUR KNOWLEDGE WITH SOCIETY AND BUSINESSES

« LIST's passion for impact is in line with Luxembourg's national research and innovation strategy. Tech Day, which brings together researchers, companies and society, provides an ideal opportunity to take stock of the many environmental and economical challenges, particularly in LIST's fields of expertise, namely digitisation and sustainability. »

Claude Meisch,
Minister of Higher Education and Research

Knowledge and innovation are increasingly recognised as important drivers of economic growth, social development and job creation.

We share our knowledge and know-how with researchers from all over the world, for example at international scientific symposiums and conferences, and with players from the public and private sectors, as well as with society as a whole. This knowledge sharing is rights-free and makes it possible to advance scientific research and education, which is something that we value particularly highly.

LIST TECH DAY: A SUCCESSFUL THIRD EDITION

Under the symbol of its motto Passion for Impact, on 22 September 2021, LIST celebrated the third edition of Tech Day, LIST's annual technology presentation event, which brought together almost 300 people at the Maison des Arts et des Etudiants in Belval, and over a hundred others through its virtual platform.

Before unveiling and showcasing no fewer than eight flagship technological innovations in the fields of energy transition, digital transition and global technological innovations, several national and international speakers took to the stage at the Tech Summit.

It enabled the participants, decision-makers, researchers and company representatives to discover the potential of a partnership with a research and technology organisation (RTO), such as LIST. This third edition of LIST Tech Day demonstrated once again that LIST is fully executing its mission to stimulate innovation in Luxembourg and to make it an attractive destination for international companies and researchers.

Thomas Kallstenius, Claude Meisch & Emanuele Barborini

LIST TECH DAY 2021
A UNIQUE WATER SAMPLER

38%
TECH DAY 2021

LIST TECH DAY 2021
TECH DAY 2021

RDI PARTNERS IN LUXEMBOURG AND EUROPE

A
- AdwäisEO
- Air Liquide
- Airbus Defence and Space
- Anisoprint
- Arcelor Mittal
- Armacell
- AXA Assurance Luxembourg

B
- BGL BNP Paribas
- BrighterBins

C
- CCB
- National Centre for Space Studies (CNES)
- Ceratizit
- Luxembourg Chamber of Agriculture
- Circuit Foil Luxembourg
- CLE
- Luxembourg National Data Protection Commission (CNPD)
- Convis
- Creos

D
- Directorate of Defence
- Directorate of Health
- Domaines Vinsmoselle
- Dupont
- Dynaccurate

E
- Electris
- Encevo
- European Space Agency (ESA)
- European Investment Fund (EIF)
- Everis

F
- Firis
- Luxembourg National Research Fund (FNR)
- Forest Climate Change Fund (FCCF)
- Frewitt
- Frontier Connect

G
- GomSpace
- Goodyear
- Gradel
- Guala Closures

H
- Hap2u
- House of Entrepreneurship
- House of Training
- Hydrosat

I
- Belgian Institute for Postal Services and Telecommunications (IBPT)
- IEE
- Institute for Training in the Construction Sector (IFSB)
- Incert
- Infrachain
- Luxembourg Regulatory Institute (ILR)
- Intrasoft international
- Institut Supérieur de l'Économie [Luxembourg Higher Institute for the Economy] (ISEC)
- ispace

K
- Kronospan

L
- Luxembourg National Health Laboratory (LNS)
- Luxembourg Institute of Health (LIH)
- Luxembourg Institute of Socio-Economic Research (LISER)
- Luxembourg Space Agency (LSA)
- Luxembourg Centre for Logistics and Supply Chain Management (LCL)
- Luxinnovation
- Luxmobility
- Luxplan
- Luxsense

M

- Ministry of the Environment, Climate and Sustainable Development (MECDD)
- Ministry of Higher Education and Research (MESR)
- Met-Lux
- National Roads Administration
- Ministry of Agriculture, Viticulture and Rural Development
- Ministry of the Economy
- Ministry for Digitisation
- Motion-S
- MPG
- Luxembourg National Museum of Natural History

N

- nhbs
- No-Nail Boxes

O

- OHB Luxspace

P

- Pierre Fabre
- PM-International
- Polygone
- POST Luxembourg
- Probiotic Group
- Proximus

R

- Research Luxembourg
- RoamsysNext
- Rotarex
- RSS Hydro

S

- Schroeder and Associates
- Sciex
- Syndicat des eaux du barrage d'Esch-sur-Sûre [Esch-sur-Sûre Dam Water Union] (SEBES)
- SecurityMadeIn.lu
- Department of Media, Connectivity and Digital Policy (SMC)
- Syndicat intercommunal pour l'assainissement du bassin de la Chiers [Inter-municipal Union for the Sanitisation of the Chiers Basin] (SIACH)
- Sisaf
- Service Moyens Accessoires [Ancilliary Means Service] (SMA)
- SmartEnds
- Spacety
- ST Life augmented
- Succy

T

- Telindus

U

- University of Luxembourg
- University of Lorraine

V

- Vaonis
- City of Differdange
- City of Luxembourg
- Vitrocell

W

- Wagner-Schaffner
- Wasdi
- Westpole
- World Alliance

X

- Xnergi

Z

- Zeiss
- ZeroK Nanotech

1

- 3D-Oxides

LIST IN A NUTSHELL

DOCTORAL THESES DEFENDED

Acerina Trejo Machin:

"Design and Synthesis of Novel Benzoxazines to Replace Traditional Reinforcing Resins in Rubber Compounds", University of Luxembourg, 23/07/2021

Adnan Imeri:

"Using blockchain to improve trust in logistics and transport processes", Paris-Saclay University (F), University of Luxembourg, 02/07/2021

Antoine Duhain:

"Cu-carbon nanostructured laminated foils: highly conductive materials with high ampacity for lightening strike protection", University of Luxembourg, 23/11/2021

Arnaud Wolf:

"An in-detailed investigation of the structure-to-property relationship between oligomeric performance resins and rubbers", University of Luxembourg, 08/07/2021

Arpan Datta Sarma:

"Enhancement of Vegetable Oil Functionality for Rubber-Composite Processing and Proper", University of Luxembourg, 02/08/2021

Bereket Abera Yilma:

"Personalisation in Cyber-Physical-Social Systems (CPSS)", University of Lorraine (F), 28/07/2021

Chuanyu Yan:

"Advanced Characterizations of Silica Surface in Rubber Compounds by Solid-State Nuclear Magnetic Resonance Spectroscopy", University of Luxembourg, 07/10/2021

Cosme Milesi-Brault:

"Old and new antiferroelectrics: Experimental studies of phase transitions in model materials", University of Luxembourg, 13/07/2021

Dominique Abessolo Ondo:

"Plasma initiated chemical vapour deposition - from the growth mechanisms to ultrathin low-k polymer insulating layers", University of Luxembourg, 15/07/2021

Edyta Niemczyk:

"Plasma-induced polymerization of liquid layers for the synthesis and deposition of Interpenetrating Polymer Network films", University of Luxembourg, 03/12/2021

Hameeda Jagalur Basheer:

"Carbon nanotube film as absorber for solar thermal energy harvesting", University of Luxembourg, 22/01/2021

Jairo Arturo Torres:

"Temporal uncertainty propagation analysis - A contribution towards sustainable urban water management", University of Wageningen (NL), 08/06/2021

Jasper Foets:

"Ecohydrological Characterization of Terrestrial Diatoms", University of Wageningen (NL), 13/04/2021

Javier Babi Almenar:

"Characterisation, biophysical modelling and monetary valuation of urban nature-based solutions as a support tool for urban planning and landscape design", University of Bordeaux (F)/University of Trento (I), 27/01/2021

Lilia Hassouna:

"Interfacial covalent chemical bonding: towards thermoreversible adhesion", University of Haute Alsace (F), 02/04/2021

Mariem Jobrane:

"The optimisation of an automated solar distillation-condensation system to produce drinking water from seawater and brackish water", University of Gabes (TU), 27/05/2021

Matteo Beggiato:

"Nanoengineered Interfaces to Enhance Analyte Mass Transport and Analyte Capture - Towards High Performance Affinity Biosensors", University of Luxembourg, 28/10/2021

Nelson Marcelo Romero Aquino:

"A Smart Assessment of Business Processes for Enterprises Decision Support", University of Lorraine (F), 18/11/2021

Nicholas Gregory Baltas:

"Dynamic Stability with Artificial Intelligence in Smart Grids", University Loyola (SP), 30/09/2021

Paul Baustert:

"Development of an uncertainty analysis framework for model-based consequential life cycle assessment", University of Eindhoven (NL), 20/04/2021

Raoul Joly:

"Structuration of piezotronic junctions for ultrasensitive strain sensors", University of Luxembourg, 10/09/2021

Sabrina Wack:

"Chemical Vapor-Phase Deposition of Nanostructured Silver Layers", University of Luxembourg, 04/06/2021

Sachin Kumar Enganati:

"Multiscale Characterization of Resorcinol Formaldehyde Latex adhesive in flexible rubber composites: Initial structure and evolution upon thermal treatment", University of Luxembourg, 01/10/2021

Tai Nguyen:

"Magnetoelectric thin-film composites for energy harvesting applications", University of Luxembourg, 19/04/2021

Thomas Elliot:

"The far-reaching impacts of urbanisation on ecosystem services and how we can tackle them", University of Lisbon (P), 14/01/2021

Valentin Ambroise:

"Impact of long-term heavy metals exposure on cold acclimation in Salix viminalis roots", Hasselt University (B), 20/12/2021

Vasu Prasad Antunes Afonso:

"Ozone Gas Sensors Based on Off-Stoichiometric Copper-Chromium oxide thin films", University of Luxembourg, 13/10/2021

Vasu Prasad Prasadam:

"Functional coatings based on MWCNT-Metal oxide nanocomposite for solar energy harvester application", University of Luxembourg, 19/11/2021

GOVERNANCE

BOARD OF DIRECTORS 2022

Photo from left to right: Robert Kerger, Candi Carrera, Caroline Roch, Diane Wolter, Thomas Kallstenius, Marie-Christine Mariani, Etienne Jacqué, Tom Battin, Eva Kremer, Isabelle Kolber, Letizia Lukas and Stéphane Jacquemart

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CEO

Stéphane Jacquemart
Chair of the Staff Delegation

GOVERNMENT COMMISSIONER

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Advisor to the Ministry of Higher Education and Research

ADMINISTRATIVE SECRETARY

Caroline Roch
Head of the Legal Department

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Professor at the École Polytechnique Fédérale de Lausanne (Switzerland)

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CEO

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Francesco Ferrero
Director, IT for Innovative Services (ITIS)

Dr Damien Lenoble
Director, Materials Research and Technology (MRT)

HUMAN RESOURCES

Kristel Wiliquet
Human Resources Director

FINANCE & ADMINISTRATION

Laurent Cornou
Administrative and Financial Director

BALANCE SHEET AS AT 31 DECEMBER 2021

APPROVAL OF ACCOUNTS

The accounts were audited by statutory auditors KPMG and approved by the Board of Directors during their meeting of 23 April 2022.

The full financial report is available at www.list.lu

Assets (in euros)	2021	2020
Fixed assets		
Intangible fixed assets	692.085,78	696.967,11
Concessions, patents, licences, trademarks and similar rights and assets	692.085,78	696.967,11
Tangible fixed assets	28.649.828,80	27.440.114,82
Land and buildings	209.293,29	331.786,91
Plant and machinery	21.660.284,72	20.397.924,66
Other fixtures and fittings, tools and equipment	2.461.630,58	1.380.744,02
Payments on account and tangible assets under development	4.318.620,21	5.329.659,23
Financial fixed assets	468.832,74	468.832,74
Shares in affiliated undertakings	415.938,20	415.938,20
Amounts owed by affiliated undertakings	-	-
Securities held as fixed assets	52.894,54	52.894,54
Total fixed assets	**29.810.747,32**	**28.605.914,67**
Current assets		
Inventories	512.659,04	488.118,66
Raw materials and consumables	512.659,04	488.118,66
Receivables	33.273.972,55	32.031.272,11
Receivables from the sale of goods and services	4.903.295,41	3.623.685,92
Other receivables	28.370.677,14	28.407.586,19
Cash at bank and in hand	73.084.941,24	68.072.784,59
Total current assets	**106.871.572,83**	**100.592.175,36**
Accruals	1.350.809,81	1.120.581,48
Balance sheet total (assets)	**138.033.129,96**	**130.318.671,51**

Equity and liabilities (in euros)	2021	2020
Equity	95.805.865,66	91.404.756,97
Capital contributions	37.518.673,70	37.518.673,70
Reserves	50.520.865,96	45.056.865,96
Profit or loss brought forward	3.365.217,31	3.757.246,04
Profit for the financial year	4.401.108,69	5.071.971,27
Provisions	320.000,00	145.000,00
Liabilities	37.574.449,82	37.933.013,71
Payments received on account for orders where not separately deducted from inventories	27.774.252,04	28.490.069,33
Trade creditors	3.821.098,86	3.128.670,36
Other liabilities	5.979.098,92	6.314.274,02
Tax liabilities	1.504.803,32	1.333.413,55
Social security liabilities	1.750.617,65	1.659.690,77
Other liabilities	2.723.677,95	3.321.169,70
Accruals	4.332.814,48	835.900,83
Balance sheet total (equity & liabilities)	**138.033.129,96**	**130.318.671,51**

PROFIT AND LOSS ACCOUNT FOR THE FINANCIAL YEAR 2021

	2021	2020
Net turnover	**7.274.166,23**	**6.884.068,34**
Other operating income	**75.869.195,81**	**71.511.472,23**
Raw materials and consumables, and other external expenses	**-15.362.225,78**	**-14.506.072,71**
Raw materials and consumables	-5.232.580,20	-5.644.615,43
Other external expenses	-10.129.645,58	-8.861.457,28
Staff costs	**-53.504.911,99**	**-50.634.886,13**
Salaries and wages	-47.217.795,12	-44.819.958,89
Social security expenses	-6.163.519,69	-5.702.174,75
covering pensions	-3.731.276,38	-3.460.167,45
other social security expenses	-2.432.243,31	-2.242.007,30
Other staff costs	-123.597,18	-112.752,49
Value adjustments	**-7.062.132,46**	**-5.498.544,43**
on formation expenses, and intangible and tangible fixed assets	-6.859.563,63	-5.451.531,47
on current assets	-202.568,83	-47.012,96
Other operating expenses	**-2.765.218,89**	**-2.663.409,01**
Other interest and financial income	**16.071,38**	**15.285,22**
derived from affiliated undertakings	-	-
other interest and financial income	16.071,38	15.285,22
Value adjustments in respect of financial fixed assets and in respect of transferable securities held as current assets	-	-
Interest and other financial expenses	**-63.835,61**	**-35.942,24**
concerning affiliated undertakings	-	-
other interest and financial expenses	-63.835,61	-35.942,24
Profit after corporate income tax	**4.401.108,69**	**5.071.971,27**
Profit for the financial year	**4.401.108,69**	**5.071.971,27**

IMPRESSUM

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Luxembourg Institute of Science and Technology

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Luxembourg Institute of Science and Technology

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Olivier Minaire, Olivier Dessy, FNR, Luxembourg Institute of Science and Technology

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