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TECHNOLOGY
RESEARCH
INSTITUTE

2018-2019

EUROPEAN ACTIVITIES REPORT



EDITO

Emmanuel Sabonnadière
CEO CEA-Leti



The digital revolution is here and, with it, new ways of working, doing business, travelling, communicating, and interacting. None of these things would be possible without the latest micro and nanoelectronics technologies from smart sensing and edge artificial intelligence to advanced computing and communications.

CEA-Leti is one of Europe's leading centers for the development of these key enabling technologies. We are designing and prototyping next-generation computing solutions that will deliver greater energy efficiency, reliability, and trust.

Why are new micro and nanotechnologies so important? First, they will make the lives of citizens across Europe better. Second, they will support Europe's technological sovereignty and help ensure that European industry remains competitive in today's global economy. Beyond computing, Europe's Green Deal also includes advanced innovations in micro and nanoelectronics. Here again, these technologies will support a more environmentally sustainable European economy.

CEA-Leti is drawing on its legendary semiconductor technologies and state-of-the-art R&D facilities to run ambitious and strategic R&D programs on disruptive innovations in edge artificial intelligence, silicon-based quantum computing, new LiDAR, beyond-5G/6G communications, augmented, virtual and XR, and connected medical devices.

European alliances and partnership are vital to the success of our multiple programs. To this end, CEA-Leti has formed an alliance with Imec (Belgium) and Fraunhofer/FMD (Germany) to develop a pan-European technological platform to design, manufacture, and test prototypes of future-generation processors and accelerators implementing new computing paradigms like neuromorphic and quantum computing. And, because cross-fertilization of European ecosystems is crucial to transitioning to a digital European economy, CEA-Leti has been collaborating with the European Digital Innovation Hubs (DIH), including the MinaSmart DIH supported by the Auvergne-Rhône-Alpes regional government here in France. Finally, CEA-Leti is leading several multi-partner EU-funded R&D projects with a broad network of partners from academic research and industrial R&D.

I would like to thank all of our partners, whether they are from industry, academia, or Europe's government institutions. Together, we are pioneering groundbreaking advances in the European digital technology space.

The following pages will show you how CEA-Leti is bringing its broad range of know-how to many of the projects that are shaping a brighter future for Europe.

Laurent Hérault
VP for Europe


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Europe is well on its way to building a more digital and environmentally sustainable economy and society. CEA-Leti is supporting the European Commission's digital and environmental strategies by pioneering advances in micro and nanotechnology that will ultimately enable new digital solutions.

Moving forward, Europe will improve quality of life for its citizens, help its businesses navigate the transition to digital technology, and shrink the carbon footprint of all sectors of the economy. Research is one of the instruments the European Commission is leveraging to enable progress in these areas.

CEA-Leti is particularly active in EU-funded multi partner R&D projects, which bring opportunities for the institute to develop new technologies and transfer them to the businesses that need them on CEA-Leti's historic market, microelectronics, as well as in the telecommunications, automotive, aeronautics, healthcare, and advanced manufacturing spaces.

This year's European Report will take you deep inside CEA-Leti's main research and development programs through the lens of the 113 multi-partner R&D projects the institute engaged in throughout 2018 and 2019. These exciting projects addressed sensors, computing, photonic devices, power electronics, wireless communications including 5G, cybersecurity, image and vision systems, medical devices, metrology, and lithography. You will discover CEA-Leti's unique contributions to each of these projects and the impacts of the research that was completed.

The results you will discover in the following pages would not have been possible without open-minded and constructive cooperation from outstanding academic institutions and industrial companies across Europe, not to mention strong support from European institutions. I am sincerely grateful for these partnerships and the opportunities they have created in terms of R&D projects and, more broadly, the European Technology Platforms (ETPs), Public Private Partnerships (PPPs), and strategic alliances with other Research and Technology Organizations (RTOs) that are vital to building shared technology roadmaps and a common vision for our future.

I hope that you will find this report both exciting and enlightening. I encourage you to join us in our efforts to continue to move European technology forward together.

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COMMITTED TO INNOVATION, CEA-Leti CREATES DIFFERENTIATING SOLUTIONS WITH ITS PARTNERS

CEA-Leti is a research institute of CEA Tech and a recognized global leader in miniaturization technologies.

CEA-Leti's teams are focused on developing secure solutions that will enable future information and communication technologies, health and wellness approaches, clean and safe energy production and recovery, sustainable transport, space exploration and cybersecurity.

For 50 years, the institute has built long term relationships with its industrial partners, tailoring innovative and differentiating solutions to their needs. Its entrepreneurship programs have sparked the creation of 65 start-ups.

CEA-Leti and its industrial partners work together through bilateral projects, joint laboratories and collaborative research programs, as illustrated in this report.

CEA-Leti maintains an excellent scientific level by working with the best research teams worldwide, establishing partnerships with major research technology organizations and academic institutions. CEA-Leti is also a member of the French Carnot Institutes network*.

* Carnot Institutes network: French network of 39 institutes serving innovation in industry.

CEA-Leti at a glance

CEA Tech is the technology research branch of the French Alternative Energies and Atomic Energy Commission (CEA), a key player in research, development and innovation in defense & security, nuclear energy, technological research for industry and fundamental physical and life sciences.
www.cea.fr/english

800
publications per year

ISO 9001
certified since 2000

114
European projects

Founded in
1967

Based in
France (Grenoble)
with offices in the
US (San Francisco) and
Japan (Tokyo)

300
industrial partners

1,850
researchers

3,100
patents in portfolio

10,000
sq. meters cleanroom space, 100-200-300 mm wafers

65
startup created

WORLD-CLASS SCIENTIFIC RESEARCH IN THE HEART OF THE FRENCH ALPS

No matter how you measure it – from academic publications and patents to startups and job creation – the Greater Grenoble area, known as "Grenoble- Alpes", is by far one of Europe's most active and prolific science and technology ecosystems. Grenoble may be small, but its student and business communities are vibrant and very international. The breathtaking mountain environment offers easy access to outdoor activities all year round.

You may be wondering just how a "minor" French city like Grenoble became an internationally-renowned hub for technological innovation. Grenoble has a long history of excellence in scientific research, but the tipping point was perhaps the advent of the Minatec micro and nanotechnology innovation campus. Minatec pioneered a groundbreaking cluster model that unites sci-tech stakeholders from education, research, and industry. Its success has inspired initiatives like the Clinatec biomedical research center, the GIANT (Grenoble Innovation for Advanced New Technologies) campus alliance of academic institutions and research organizations, the EU Nano2022 program to develop a new generation of semiconductors, and, most recently, MIAI (the Multidisciplinary Institute in Artificial Intelligence) – all located in Grenoble. Grenoble is also home to top-tier academic institutions: Grenoble-Alpes University, Grenoble Institute of Technology, and Grenoble Ecole de Management have all earned top slots in the major international university rankings.

Finally, international large scientific instruments like the European Synchrotron Radiation Facility (ESRF) and the high-flux neutron beamline at the Institute Laue-Langevin (ILL) are just down the street from Leti in Grenoble's research district.

R&D-intensive industries like microelectronics, nanoelectronics, medtech, energy, and cleantech are staples of the local economy. And a number large industrial corporations serving international markets have located their R&D divisions in Grenoble. The high concentration of tech-oriented businesses and a strong fabric of more traditional manufacturing companies have made Grenoble particularly fertile ground for collaborative innovation projects – **often funded through EU** and national instruments – designed to rapidly bring novel concepts from lab to market.

Although Grenoble – a medium-sized city – may not be a European capital, it is a wonderful place to live. The city center is compact and very walkable, placing a wide range of everyday activities within easy reach. The population is extremely cosmopolitan. In fact, Grenoble is home to the second-largest English-speaking population in France, second only to Paris. But what people who live in Grenoble consistently rave about is the mountain environment. From downtown Grenoble it is possible to access major hiking trails by car within minutes, and the suburbs (and even the city center) are dotted with trailheads that can be reached by public transportation and, in some cases, on foot. Major ski resorts are close enough to make hitting the slopes for a half a day during the week a reality. A dynamic network of sports clubs is available to help newcomers discover all that is on offer.

People come to Grenoble to study or conduct research. But they stay for excellent career opportunities and top-notch quality of life.

First place for R&D

First in France for R&D jobs

Second in France for engineering jobs

A GREAT PLACE TO STUDY
The Shanghai Academic Ranking of World Universities named Grenoble-Alpes University no. 1 in France for:
- Computer Science
- Electrical & Electronic Engineering
- Energy Science
- Water Resources Engineering
- Nanoscience & Nanotechnology
- Instruments Science & Technology

Grenoble's student population of 62,000 stands out for its diversity and excellence:
- 42% in science, technology, and engineering
- 3,700 PhD candidates
- 180 nationalities

…AND LAUNCH A CAREER!
The Greater Grenoble area is home to a workforce of 340,000:
- 28,000 engineers
- 23% management, well above the national average of 17%



Invest in Grenoble Alpes

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EU RTOS COOPERATION FOR NEXT-GEN COMPUTING

Encouraged by the European Commission, the three major European Research and Technology Organizations (RTOs) in microelectronics research and development, CEA-Leti, Fraunhofer/FMD and imec, are collaborating through a strategic alliance to develop the necessary compute platforms enabling new applications in healthcare, industry, mobility, etc., where technologies for artificial intelligence, high-performance computing and cybersecurity become indispensable.
This unique world-leading collaboration focuses on full technology and engineering development on 300mm wafers to realize the European hardware for the new compute infrastructure. This new initiative opens up an affordable, fast-track access for SMEs. and systems houses in Europe.


© TEMPO

EU project TEMPO targets low-power chips for AI applications based on emerging memory technology.
TEMPO project brings together the three top European RTOs, industrial fabrication facilities and leading application partners in the domain of neuromorphic computing, which features intense global competition towards the vision of intelligent machines. The objectives of TEMPO is to design and combine performing transistors and new emerging memories to realize new neural networks that will be able to analyse complex situation like object detection in real time (automotive, space, health,...multiple applications).

Emmanuel Sabonnadiere, CEO at CEA-Leti:
"It is our aim to sweep technology options, covering emerging memories, and attempt to pair them with contemporary (DNN) and exploratory (SNN) neuromorphic computing paradigms. The process- and design-compatibility of each technology option will be assessed with respect to established integration practices and meet our industrial partner roadmaps and needs to prepare the future market of Edge IA where Europe is well positioned with multiple disruptive technologies."

Prof. Hubert Lakner, Director of the Fraunhofer Institute for Photonic Microsystems (IPMS) and Chairman of the Board of Directors of the Fraunhofer Group Microelectronics :
"A key enabler for machine learning and pattern recognition is the capability of the algorithms to browse through large datasets. Which, in terms of hardware, means having rapid access to large memory blocks. Therefore, one of the key focal areas of TEMPO are energy efficient nonvolatile emerging memory technologies and novel ways to design and process memory and processing blocks on chip."

Luc Van den hove, CEO imec:
"We are delighted to enter in such broad European collaboration effort on Edge Artificial Intelligence, gathering the relevant stakeholders in Europe, including CEA-Leti and Fraunhofer, two of our most renowned colleague research centers in Europe. Thanks to our combined expertise, we can scan more potential routes forward than what would be possible by each of us individually, and as such, position Europe in the driver seat for R&D on AI. Imec looks forward to the progress we can make together in the TEMPO project and hopes this will lead to more similar collaborations in the future. Behind the scenes, we are already defining more public and bilateral agreements with several of the partners involved."



Christophe Wyon
Deputy Head of European Affairs
CEA-Leti

IPCEI ON MICROELECTRONICS

At the end of 2018, the European Commission approved the Important Project of Common European Interest (IPCEI) on microelectronics under state aid law. This allowed four European member states to support jointly transnational cooperation projects with major synergies in microelectronics – for the first time until the end of first industrial deployment. The IPCEI on Microelectronics is an instrument that enables France, Germany, Italy and the United Kingdom to maintain and further expand European competencies in this field and to ensure that the entire microelectronics value chain is reliably available to local players.

These four countries are providing up to €1.75 billion in funding for this project, which intends to unlock an additional €6 billion in private investment. These state aids are dedicated to promoting development of new microelectronic products across industry and national borders. The IPCEI on microelectronics brings together the wide-ranging family of microelectronics topics, e.g. optics development, hardware design, process knowledge, production facilities, chip manufacture and downstream applications in multiple industries. Twenty-nine European companies are directly involved in the «IPCEI on Microelectronics».

This Important Project is divided into five technology fields (TF): energy efficient chips, power semiconductors, sensors, advanced optical equipment and compound materials. CEA-Leti is closely cooperating with French industrial partners in four of these fields. CEA is also involved in European projects linked to this IPCEI, such as ECSEL projects (OCEAN 12, WAKEMEUP, VIZTA, HELIAUS, BEYOND 5, etc.), in which it is cooperating with European industrial partners of the IPCEI on microelectronics.

In the TF involving energy efficient chips, CEA-Leti is developing advanced substrates for 5G RF communications, new FDSOI- and RFSOI-based architectures using the unique properties of SOI substrates, 3D monolithic integration of transistors, emergent embedded non-volatile memories based on PCRAM and ReRAM, and more. These developments are mandatory for optimizing the electronic properties of next-generation conventional devices and for integrating their results into brand new component architectures such as memory-centric neuromorphic computing, which appears highly significant for extreme edge Artificial Intelligence.

Within the scope of the power semiconductors TF, CEA-Leti is developing and improving new power device design and processes based on 200 mm diameter GaN/Si technology. This research is enabling process parameter sets to be controlled to achieve high-performance, robust and reliable GaN transistors and components. CEA-Leti is also developing high-performance passive devices such as capacitances and inductances for power devices.

CEA-Leti is investigating new architectures and advanced processes for increasing the sensitivity and integration density, and reducing the power consumption, of visible and IR image sensors. These studies range from implementation of hybrid bonding at wafer level to development of fine-tuned micro-lenses through research into new pixel architectures.

In the compound materials TF, CEA-Leti is developing new II-VI and III-V materials and processes for improving the image quality of IR focal plane arrays. It is also investigating new substrates and technologies for micro-LEDs. Furthermore, it is improving the design and processes of components, such as laser sources, waveguides, micro-resonators, photodetectors, etc., which are essential to widespread deployment of integrated silicon-photonics.

The involvement of CEA-Leti in a major, ambitious and very important R&D project such as the IPCEI on microelectronics is allowing CEA-Leti to strengthen its cooperation with European industrial partners.

minaSmart Auvergne-Rhônes-Alpes

With the objective of spurring and helping European industry to adopt digital technologies, the European Commission has strived to structure a discussion at the European scale around the concept of European Digital Innovation Hubs (EDIH). In this context, a holistic and symbiotic approach integrating hardware, software and digital usages is essential. This approach includes services, systems (for example: cars, planes, factories, hospitals, etc.), equipment/functions and components.

minaSmart Auvergne-Rhône-Alpes, in collaboration with a pan-European network of European Digital Innovation Hubs, intends to provide for all economy stakeholders willing to benefit from the advantages of digital technologies in their businesses (SMEs, small caps, large enterprises, public organizations, etc.):

- access to necessary technologies and skills
- an understanding of use cases, the value chain and the supply chain
- an acceleration of R&D
- support services related to innovation
- field trials for experimenting with digital innovations

In order to achieve these objectives, minaSmart Auvergne-Rhône-Alpes leverages the Auvergne-Rhône-Alpes region's capacity to reinforce the hardware-software continuum on 6 key digitization technologies:

- high-performance computing and simulation
- artificial intelligence
- cyber-security and privacy
- connectivity (5G and Internet of Things)
- integrated and smart microelectronic components
- cyber-physical systems

The EDIH mobilizes key players in the above fields, allowing to support 2 main targets, start-ups/technological SMEs and non-technological SMEs, enabling the DIH to offer end-to-end services including:

- start-ups/technological SMEs:
  - stimulation of ideas through the organization of «brokerage» and networking events (brainstorming and thematic open days of competitive clusters)
  - support services for business development (marketing, intellectual property, capital risk management, relations to major order givers, etc.)
  - access to skilled resources on «hard-to-fill» jobs in digital sector (Campus Région du numérique, school Le 101, etc.)
  - access to skills and advanced technological platforms (EuroCPS and FED4SAE European projects, Nanoelec IRT, collaborative projects of competitive clusters, SATT Linksium, etc.)
  - analysis of the societal impact, by humanities and social sciences, and with living/citizen labs
- non-technological SMEs:
  - technological awareness (e.g Cap'Tronic program, etc.)
  - support for technology transfer (e.g EASYTECH program, etc.)
  - access to platforms and pilot lines to help the digital transformation of industrial production sites / factory of the future (Charbonnières 2020 project, etc.)
  - access to skilled resources to support changes brought by digital technologies

The ambition of minaSmart Auvergne-Rhône-Alpes is to serve the industry of the Auvergne-Rhône-Alpes region and at the same time to expand and serve at national and European levels. The Auvergne-Rhône-Alpes Region has exceptional public and industrial infrastructures to design and develop smart objects integrating software and components, ranging from imaging sensors to components for low-power computing, and also services necessary for digital transformation of enterprises. In addition, Grenoble's strong international links in the areas combining hardware and software (tied within European pilot projects for DIH networks such as DIGIFED, EuroCPS, FED4SAE and SMARTEES, and a network of clusters such as the SILICON EUROPE alliance) will help develop closer links with corresponding undertakings in other European countries.

minaSmart Auvergne-Rhône-Alpes has been initiated by CEA-Leti, and relies on a large network of partners distributed throughout the Auvergne-Rhône-Alpes Region in key application sectors in the heart of the region's smart specialization strategy:

- health
- transportation and smart mobility
- energy
- chemistry and environment
- agritech / foodtech
- industry of the future

The core team includes:

- the « Région Auvergne-Rhône-Alpes », the « Campus Région du numérique » , and the agency Auvergne-Rhône-Alpes entreprises
- CEA and Inria
- the Université Grenoble Alpes and the Université de Lyon
- the competitive cluster MINALOGIC
- the Carnot institutes of the region
- the Nanoelec Technological Research Institute

minaSmart Auvergne-Rhône-Alpes relies on nodes throughout the Auvergne-Rhône-Alpes Region, including Lyon, Grenoble, Saint-Etienne and Clermont-Ferrand, and has established privileged links with other major national European Digital Innovation Hubs such as DIGIHALL in Paris-Saclay, and European DIHs from the SILICON EUROPE alliance. In addition, minaSmart Auvergne-Rhône-Alpes will benefit from the hardware platform dedicated to future generations of computing components, currently under preparation between CEA-Leti, imec (Leuven, Belgium) and Fraunhofer-Verbund Mikroelektronik (Dresden), thus responding to the recommendations made by a high level group of the European Commission (Electronics Leader Group).



HIGHLIGHTS

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Isabelle CHARTIER

Gateone

CEA-Leti's main contribution to the success of the Gateone project has been its offer of more than 25 mature Key Enabling Technologies (KET) for smart systems to SMEs. These range from sensors to communication, energy management and cybersecurity systems.
The project's European dimension has enabled CEA-Leti to build 14 market-pulled demonstrators illustrating the potential of its KET portfolio to industrial partners and enhancing the SME business model of the most promising demonstrators.
The project has led to a number of breakthroughs including incubation of MAG4Health and creation of MOOVLAB start-ups. MAG4Health will develop a magnetoencephalography imaging technique that measures brain activity. The proof of concept and subsequent progress has prompted strong interest from the medical community. Gateone funding has helped to the design the first bricks of the currently operated, MOOVLAB wearable gym motion tracker. The start-up is now launching its first product and interactive workout video class for gyms.
The Gateone model supporting SME-RTO demonstrator production has been adapted and duplicated in France's Isère Rhône-Alpes regional cluster. CEA-Leti also coordinates FED4SAE and DIGIFED European projects based on Gateone's return on experiment.
More information p.36



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Guido RADEMAKER

IONS4SET

Among multiple contributions, CEA-Leti's patterning service has been the development hub for nanopillar patterning, trimming and selective etching. In-line CD-SEM metrology and in-line tilted SEM imaging techniques characterized the influence of different process parameters.
The German coordinator and the Spanish, Finnish and Italian partners of the IONS4SET project have been indispensable to meeting its need for wide ranging technologies: quantum device and Si+ ion implantation simulations, Si+ nanodot formation, sacrificial oxidation and de-oxidation, TEM lamella preparation, GAA creation, electrical contacting, and FET-SET device creation for an electrical demonstrator. Novel hardware, software and testing techniques have been created within the project scope and device performance has been measured.
Project breakthroughs for CEA-Leti have included reproducible patterning of nanopillars containing nanodots for CMOS-compatible SETs, with diameters of less than 20 nm on 200 mm wafer-scale.
More information p.254

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Etienne LABYT

BONVOYAGE

CEA-Leti expertise in database collection and machine learning has contributed powerfully to the success of the BONVOYAGE project, in particular via its Internames paradigm, which allows named entities to communicate without static binding to a specific location.

Cooperation between partners in the European transport sector has enabled benchmarking of project developments and feedback from project meetings has fostered development leverage.

New algorithms for user transport mode recognition and traveller stress level assessment have been developed by CEA-Leti and represent major project contributions. For the former, a unique database of modal smartphone-embedded sensor recordings was created and used to develop a first algorithm. For the latter, a first algorithm was developed for acquiring data from a single wearable and providing feedback to the traveller on his/her stress level. This algorithm was embedded in the final BONVOYAGE App as a demonstrator and in a CEA-Leti Android App providing scientific and technological proof of concept of stress assessment.

Trenitalia, a first multimodal door-to-door journey schedule embedding BONVOYAGE platform functions in a dedicated App was delivered at the end of the project. *More information p.24*


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Elise SAOUTIEFF

InDeal

Success of the InDeal project has been the outcome of CEA-Leti expertise in energy harvesting systems and its design, modelling and testing skills for in-line smart water meters. The project has contributed significantly to reversing today's unsustainable energy consumption and living up to revolutionary policy expectations. In addition to ensuring funding dedicated to research at low technology readiness levels (TRL), the project's European dimension has enabled CEA-Leti to develop its research network and expertise through strong cooperation with researchers from other centres, with new SMEs and with district heating and cooling association partners. Access to project partner's laboratories for microturbine optimization testing and testing of project-developed devices in real heating and cooling system environments has also contributed powerfully to the project's success.

CEA-Leti has derived a number of valuable breakthroughs from InDeal including development of eco-efficient, eco-friendly, cost effective district heating and cooling solutions (DHCS), specifically an optimized water flow energy harvester and a thermal energy harvester. Ultimately, the project breakthroughs could be embodied by autonomous flowmeters and, more generally, by autonomous in-line sensor systems for water distribution networks. *More information p.42*


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Vincent DELAYE

3DAM

CEA-Leti was leader of a metrology and structural analysis work package and provided 300mm FEOL and BEOL advanced samples (test wafers) for the 3DAM project partners for developing new in-line metrology capabilities. The expertise of CEA-Leti teams in 3D characterization and data processing on CEA-Leti's Platform for NanoCharacterisation (PFNC) made it possible to establish new hybrid or correlative measurement protocols in cooperation with dedicated partners.

CEA-Leti collaborated with partners imec and ThermoFisher Scientific in developing additional characterization techniques, such as electron tomography and X-ray tomography for FEOL and BEOL qualification, cathodoluminescence and photoluminescence techniques for defect characterization and identification, TEM and micro-RAMAN techniques for strain analysis.

At CEA-Leti, 3DAM partner Applied Materials tested a new algorithm developed to measure 3D structures such as stacked nanowire FETs. This new capability is now used in other clean room applications including High Electron Mobility Transistor (HEMT) technology. Methods and protocols developed on the PFNC during 3DAM are now available for CEA-Leti programs including GUIDAR software for 3D reconstruction, quantitative energy dispersive spectroscopy (EDS) protocols and two correlative approaches combining TEM and optical techniques. *More information p.236*


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Fabrice NAVARRO

NEW DEAL

CEA-Leti's key to the success of the NEW DEAL project has been the multidisciplinary nature of its Department of Micro- and Nano-technologies for Healthcare and Biology in terms of developing a nanotechnology-based pharmaceutical product. Its collaboration with CEA IRIG's team and access to the µ-life platform's state-of-the-art instrumentation were also major contributions.

NEW DEAL's European dimension was needed to gather critical expertise in pharmaceutical sciences, in molecular biology, in nanomedecine and in vivo testing, and to achieve compulsory certification for new therapeutic applications and clinical trials of siRNA nanomedecine. Other project partners recorded and released several explanatory videos targeting a wide audience. Consultant Alan Boyd provided valuable insight and assistance in devising a clinical plan in line with European pharmaceutical regulatory requirements for bio-therapies.

The project has effectively promoted Lipidot technology, which is patented and owned by CEA to a level compatible with standards enabling its therapeutic use. However, the real breakthrough has been not only the actual intended short interfering RNA (siRNA) drug for treating inflammatory bowel disease (a biomacromolecule), but also the underlying goal of in vivo validation and approval of the Lipidot nanodelivery system for human trials. *More information p.218*


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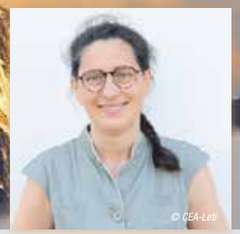
Jean-Guillaume COUTARD

REDFINCH

Throughout the REDFINCH project, CEA-Leti's research and development capabilities have enabled advanced technologies, typically MEMS and integrated photonics on silicon, to be combined from design stage all the way through to demonstrator testing. Demonstrators developed are PIC-based chemical sensors for process gas analysis, gas leak detection and protein analysis.

The project's European dimension has been key to ensuring access to a broad spectrum of complementary expertise provided by the partners, which include end users and specialists in gas analysis and spectrometry in liquids. The REDFINCH website, conference communications and press releases have allowed first contacts to be established with potential industrial stakeholders, such as BP, BAE Systems and Thorlabs, and the US Navy's research laboratory.

REDFINCH has contributed to consolidating Quantum Cascade Laser (QCL) technology specifically for photoacoustic (PA) spectroscopy. A miniaturized silicon PA cell has been fabricated using standard CMOS / MEMS tools, thereby reducing the cost, extreme integration and mass deployment of these sensors. Centimeter-size PA cells for gas sensing have been demonstrated to compete with bulky commercial systems without compromising performance. *More information p.52*


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Maeva DORON

D4KIDS

D4KIDS is gearing the Diabeloop Artificial Pancreas (AP) device to the needs of children with Type 1 diabetes (T1D) and their families. Based on a co-creative approach and clinical evidence, the project is improving pediatric care, enhancing long-term T1D trajectories and quality of life, and increasing European healthcare sustainability.

The main project challenge has been to determine the estimation in real-time, every five minutes, of the right insulin dose requiring adaptation to carbohydrate intake, physical activity, instantaneous blood glucose and variable basal insulin for children, who lead irregular, intensely physical lifestyles.

The device and age-appropriate training will enhance societal knowledge of T1D, increase its acceptance and reduce stigmatization and long-term complications.

D4KIDS involves a highly advanced AP in terms of TRL, CE marking, marketing and reimbursement potential. It has strong industrial backing and brings together EU partners to facilitate market uptake.

The project consortium has established focus groups in France and Belgium to dialogue with future closed loop users and run a successful clinical trial.

The European team has extended the competence a 2015 French consortium and has been awarded the teenager-targeted D4TEENS EIT project. *More information p.198*

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François ANDRIEU

My-Cube

My-CUBE is leveraging non-volatile resistive memory, new energy-efficient nanowire transistor and 3D-monolithic enabling technologies towards a function-enhanced system closely entangling logic and memory. This is the only technology capable of supporting the scalability of the In-Memory-Computing (IMC) concept.

My-CUBE's new nanotechnology is enabling design, fabrication and measurement of a 3D accelerator circuit, which targets a 20x reduction in (Energy x Delay) Product compared with von Neumann systems. Project material science, electrical engineering and circuit design is co-optimizing the technology and circuit.

The computational kernel of upcoming European energy-efficient circuits can benefit in the future from this project by integrating the game-changing memory-storage smartness provided by My-CUBE technology.

The project team benefits from the CEA-Leti eco-system, which embraces unique expertise in CMOS, NVM and advanced characterization, while offering 300 mm cleanrooms and circuit design platforms. Advanced transistors for memory cube selectors have been studied in depth and the cube is designed based on SPICE simulation and newly fabricated mask sets.

We have developed new capabilities in IMC, a novel computing paradigm effectively spanning 3D packaging, memory and logic nanotechnologies based on an unconventional holistic, multidisciplinary approach. *More information p.82*



Sylvie MAYRARGUE

MiWaveS

The aim of the MiWaveS project, completed in 2017, was to develop key technologies for implementing millimetre wave (mmW) wireless access and backhaul in heterogeneous networks.

The challenges taken up in this CEA-Leti-coordinated project involved designing new backhaul E-band transmitarray antennas with beam switching capability, new low-cost and low power antenna/RF packaging at 60GHz for user terminal, and, based on the same chip, a new phased array architecture for 60GHz access points. These are key building blocks for developing 5G cellular network- and reducing user terminal transceiver chip consumption.

The project has thus placed Europe in the forefront of mmW technology for 5G and 6G deployment, addressing the main issues of cost and consumption at the user terminal, and of beam steering/switching at the access point. In addition, a specific mmW transmitarray electromagnetic lens has been developed for high gain backhauling, together with an active focal array including switching and phase-shifting functions. The antenna concept was developed for industry and Radiall is now manufacturing and marketing the first E-band products based on MiWaveS technology. Finally, cooperation is ongoing with STMicroelectronics (24 GHz radar, 60 GHz short range communication chips), Thalès (wide band beam steering satcom antennas) and Remedee Labs (mmW personal endorphin stimulator for pain management), among others.

More information in the previous report p. 146


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Emilio CALVANESE-STRINATI

5G CHAMPION

The 5GCHAMPION project developed 5G key enabling technologies for a proof-of-concept environment showcased at the 2018 Winter Olympics in Pyeong-Chang, South Korea. It provided maximum visibility of 5G technology and answers to 5G's unknown performance two years before its official launch. On a global level, the project successfully impacted standards and regulation bodies through a common European/Korean position and engineering of its technologies and proposed solutions.

Success was achieved through the technical excellence of the project contributors and the outstanding leadership of Europe's CEA-Leti and Korea's ETRI coordinators.

The professional and personal capabilities essential to the project included the need to finalize all facets of the research, the technical knowledge to take up its multiple challenges and a real understanding of the respect, accuracy and rigor central to Korean culture.

CEA-Leti's know-how in antenna design, interference mitigation and 'xG' network architecture, design and engineering were key to project success and participation of CEA-Leti's key expert drove its multiple contributions .

Finally, 5GCHAMPION has made millimetre wave implementation a reality for urban mobility through its validation of key enabling technology.

More information p.136

MFMANUFACTURING: CONTRIBUTION TO ISO STANDARDISATION

In the wake of the MANUFACTURING project, completed in 2017, the Microfluidics Association has been founded to coordinate the international community and propose guidelines for future standards dedicated to microfluidics standardisation. Nicolas Verplanck has been appointed convenor of ISO TC48/WG3 and CEN TC332/WG7 working groups drafting these standards, the first of which is under preparation.

The main factor for standardisation success is that the principal microfluidics stakeholders have now achieved maturity and, while remaining competitors, understand the need to cooperate in proposing standards to grow the market and offer reliable, economical solutions.

Today's microfluidics leaders are mostly European and the MFMANUFACTURING consortium embraces every typology. The Project Officer has been vital in challenging team decisions and results and in pushing for relevant outputs.

Technical expertise and knowing the leading SMEs, academics and standardisation bodies have been central to the professional and personal capabilities implemented. CEA-Leti initiated the MFMANUFACTURING project and has positioned itself as RTO leader in microfluidics based on its coverage and hybridization of polymer, silicon and glass materials. The Institute's clear visibility has bridged the gap between industry, which needs standards, and academic organisations, which are unfamiliar with them.

More information in the previous report p. 204


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Nicolas VERPLANCK

NeuRAM3


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Elisa VIANELLO

The NeuRAM3 project involved fabricating a mixed-signal analog/digital chip implementing neuromorphic architecture as well as developing monolithically integrated 3D technology in Fully-Depleted Silicon on Insulator (FDSOI) based on 28nm design rules with integrated Resistive Random Access Memory (RRAM) synaptic elements. Project complementary technologies included implementing on-chip learning using native adaptive characteristics of electronic synaptic elements and a scalable platform to interconnect multiple neuromorphic processor chips for building large neural processing systems.

The project achieved success through its consortium's multidisciplinary co-development of algorithms, devices and circuits enabling novel neuromorphic architecture based around RRAMs that emulate biologically plausible synaptic behaviour co-integrated with state-of-the-art CMOS logic for new circuits and systems.

CEA-Leti's capabilities contributed to every aspect of the project and, specifically, its expertise in integrated RRAM synaptic elements and monolithically integrated 3D FD-SOI technology. NeuRAM3 has prompted more than 50 publications in international journals and multiple conference presentations including at the Nature Conference on Neuromorphic Computing as well as a new EU ICT RIA project, entitled Mem-Scales, involving memory technologies with multi-scale time constants. *More information p.84*

MIRPHAB

The MIRPHAB pilot line project involves developing MIR chemical sensors for mass markets by embracing the full supply chain (source, detector, PICs, assembly and packaging), supporting and encouraging large scale adoption of Mid-IR Optical Sensing and driving Mid-IR Sensing Market growth. These goals are supported by miniaturizing and standardizing mature existing technologies for Mid-IR miniaturized components, developing interfacing and assembly technologies and producing user specification-based SiP/SoC demonstrators.

The project's key success has been to structure and coordinate the full supply chain through its inclusion of Europe's main stakeholders in Mid-IR chemical sensing. Dissemination of MIRPHAB work has contributed strongly to a change in paradigm regarding Mid-IR sensing technology for industrial and consumer applications.

Coordinating this challenging project involving multiple consortium partners required negotiation skills and the capability for collecting, summarizing and elaborating common strategies. Knowledge of the gas/chemical sensing market and communication skills was key to its success.

CEA-Leti was at the project core in terms of driving criminal detection-related optical sensor miniaturisation and combining different technologies on a common Si platform.

More information p.44


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Sergio NICOLETTI

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SENSORS

- Abacus
- ADVANTEX
- ASTEROID
- BONVOYAGE
- COBRA
- CONVERGENCE
- Enlightened
- EuroPAT-MASIP
- EVERLASTING
- GATEONE
- HADRIAN
- iCspec
- InDeal
- MIRPHAB
- POSITION-II
- PreCoM
- PYCSEL
- REDFINCH
- SAFESTRIP
- SARMENTI
- SILENSE
- SPEED 5G

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Abacus

Algae for a Biomass Applied to the Production of Added Value Compounds

The bioproduction industry is focusing attention on microalgae due to their ability to synthesized internally high added-value molecules. The ABACUS project aims to identify microalgae capable of producing new molecules for nutraceutical and cosmetic applications, and to develop an innovative PhotoBioReactor that embeds advanced monitoring tools for microalgae growth and bioproduction.

http://www.abacus-bbi.eu/

Keywords
Algae
Carotenoids
Photobioreactors
Terpenes

Abacus at a glance

36 months
May 2017 > Apr.2020

EC Programme
BBI-RIA (Bio Based Industries – Research and Innovation Action)

Project Coordinator
CEA-Tech PACA (FR)

Partners
DE: Karlsruher Institut für Technologies, Subitec
FR: CEA, Microphyt, Proteus, Sensient
PT: Algae 4 Future
SP: Conseja Superior de Investigaciones Cientificas
UK: Scottish Association for Marine Science

Total budget
€ 5.1 m.

EC Contribution
€ 4.6 m.

Contract Number
745668

Objectives

ABACUS brings together two major industries, three algae SMEs and four RTOs. It focuses on business-oriented, technology-driven development of a new algal biorefinery. This will bring to the market innovative algae-based ingredients for high-end applications ranging from algal terpenes for fragrances to long-chain terpenoids (carotenoids) for nutraceuticals and cosmetic actives.
One key objective of ABACUS is to obtain more than 10% photosynthates of its targeted terpenoids. To achieve this, ABACUS selects and optimizes unique algae strains from 4 large culture collections owned by the project partners.
ABACUS also focuses on optimizing cultivation stages and mastering production of target products by online monitoring and automated control of photobioreactors with the development of specific sensors for terpenes and for the parameters relevant to terpene production (light, PO_2, PCO_2, nutrients). The project investigates the process fractionation steps to provide green low-cost downstream processing with a view to reduce operating costs of the entire production line.
Life cycle analysis and techno-economic analysis are fundamental guidelines of ABACUS's developments to ensure that technologies and products are economically and environmentally sustainable. Applicability of targeted ingredients is assessed by the industrial partners (SMEs and large industries with established access to markets) in relation to cosmetic and nutraceutical applications. ABACUS aims to demonstrate biorefining processes allowing valorizing up to 95% of the algal biomass into high value ingredients and by-products. EU standards and market regulations related to innovative bioprocesses and new ingredients are reviewed to demonstrate the acceptability of the ABACUS biorefinery. The project's prime advantage lies in its business-oriented work plan, which brings together key players throughout the product development chain and integrates cutting edge technologies for efficient growth and fractionation of microalgae.

CEA-Leti in Abacus

Within the ABACUS project scope, CEA-Leti is responsible for sensor development, adaptation and integration for precise monitoring and control of the algal bioproduction process. Three different sensing platforms were developed during the first 18 months of the project:

- A multiparameter electrochemical platform, based on Ion Selective Electrodes (ISE) for in-situ monitoring of crucial ionic nutrients (nitrate, phosphate and ammonium) involved in optimizing culture conditions. An acquisition card, combined with a software interface and a fluidic chamber enabling static or dynamic measurements of the algal process, have also been designed.

- A stand-alone optofluidic system automatically measuring culture medium optical density at four different wavelengths (880nm, 750nm, 680nm and 474nm) along with an automated dilution process for estimating algae concentration during growth and production of selected molecules.

- An gas chromatography-based analytical system with a miniaturized micro-preconcentrator and micro TCD for detecting volatile terpenes in the gas phase.

Validation using model samples was carried out in all cases. In the coming months, tests are planned with real samples under real operating conditions; these will allow fully evaluation of sensor performance.



Optofluidic system developped by CEA-Leti.
© CEA-Leti

IMPACT

Microalgae are fast-growing photosynthetic organisms that are able to double their biomass twice a day without applying pesticides, herbicides or fungicides. Moreover, they can produce target high added-value molecules, when carefully selected and efficiently directed during growth, through controlled induction using selected nutrients (nature and concentrations) and controlled physicochemical stress. The ABACUS project aims to position an European algal biorefinery beyond the state of the art through development of advanced bioreactors that provide full control of the bioproduction chain. Its goal is to design innovative fractionation technologies that allow high-yield algal bioproductions.

While CO_2 trapping by algal bioproduction remains minor, "green" production of complex high added-value chemicals using biorefineries is strategic in the context of global warming.

From the CEA-Leti standpoint, development of new sensing platforms (electrochemical, optofluidic, µGC) extends the Institute's offer in the field of process monitoring sensors. Interestingly, the ABACUS project paves the way towards CEA-Leti's further involvement in bioproduction, which was declared a strategic market by the French government in 2019.

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Florence Ricoul
florence.ricoul@cea.fr



ADVANTEX

Objectives

ADVANTEX focused on improving the safety of workers facing hazardous conditions including fire-fighters, waste and recycling workers, steel, foundry and glass industry workers. This goal was achieved by developing intelligent condition monitoring and detection systems based on sophisticated, miniaturized sensors that can be integrated into smart protective clothing.

The ADVANTEX microsystem can monitor a worker's physiological condition and detect abnormal conditions regarding posture, breathing, heartrate, humidity, etc. The system also monitors the surrounding environment to detect dangerous gases and to measure temperature and humidity for monitoring heat capacity/stress. Specifically for protecting fire-fighters, a control centre has been developed that implements wireless communication to provide real-time monitoring of movement, localization and other critical parameters.

The technology is based on integrating high-tech components and sensors (MEMS and UHF RFID). Demonstrators exhibiting the desired properties, based on the project specification, have been developed and fabricated, while technology procedures have been up-scaled and applied to production.

Beyond the direct application for enhancing the safety of worker operations, ADVANTEX developments may offer potential applications in the medical field, for example Alzheimer patient monitorin, and may improve performance training and position tracking in professional sports.

www.apixanalytics.com/wp-content/uploads/2016/01/fiche-projet-Advantex.pdf

Keywords
Sensors / Actuators
Smart textiles
Through Silicon Vias (TSV)

ADVANTEX at a glance

48 months
Apr. 2014 > Mar. 2018

EC Programme
EURIPIDES 2013

Project Coordinator
APIX Analytics (FR)

Partners
FR : APIX Analytics, CEA-Leti, Movea (> InvenSense)
CZ : Applycon, Holik, University of West Bohemia, Vochoc

Total budget
€ 5.9 m.

EC Contribution
NA

Contract Number
13-1504

Advanced Functional Blocks And Technologies For Smart Textile Products

The aim of the AVANTEX Project was to develop firefighting protective clothing (jacket, gloves and boots) for monitoring work situations (localization, temperature, humidity, flammable gas detection) and personnel safety.

CEA-Leti in ADVANTEX

Progress was clearly visible in the ADVANTEX project with significant advancements made in technical textile technologies. The project was structured to allow for several iterations of sensor and sub-system development and integration in firefighting personal protective equipment (clothing, gloves and boots). Each sequential improvement built on an existing clothing product line, allowing rapid deployment of innovation in successive products. CEA-Leti contributed strongly to developing improved sensors and wireless communication between sensors and the central processing unit carried by the firefighter. A unique wireless RFID tag reader was used to transmit power remotely and to interrogate sensors and read out their signals.

Bulk acoustic wave gas sensors were developed along with process optimization to achieve a 2.4 GHz resonant frequency. Sensor functionalization can be programmed to allow detection of several different gases. Hydrogen detection was tested but required optimization to reach the desired selectivity (use of multi-layer functionalization). In parallel, Nano-ElectroMechanical microSystem (NEMS)-based gas detection sensors were also examined for the firefighting environment. NEMS relied on the piezoresistive resonant excitation of a free-standing cantilever, which was functionalized to detect a specific gas or family of gases. This type of sensor could eventually be integrated using the product offer of APIX Analytics, a start-up company created by CEA-Leti.



© ADVANTEX project

IMPACT

The ADVANTEX project enabled a smart vest, smart boots and smart gloves for firefighters to be designed and manufactured. Multiple sensors were implanted in each item and connected to the body unit, which collects information and communicates with a central unit monitoring several firefighters on site.

Publications

Keynote and invited presentations at the following conferences:

- *ISSE – International Spring Seminar on Electronics Technology 2016 HAZMAT.*
- *Protect 2016 Smartatfire final conference, Brussel 2016.*
- *Swiss e-print, Basel 2017.*
- *ECPC European Conference on Protective Clothing, Porto 2018.*

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Thierry Claret
thierry.claret@cea.fr

Yves Quéré
yves.quere@cea.fr



ASTEROID

Astronomy European Infrared Detector

ASTEROID is an European Union-funded H2020-COMPET project. Its purpose is to provide Europe with the capability to manufacture high performance, high-resolution infrared focal plane arrays for scientific and astronomical use in space- and ground-based telescopes.

https://asteroidh2020.eu/

Keywords
Astronomy
Infrared detection
Space

ASTEROID at a glance

40 months
Apr. 2017 > Aug. 2020

EC Programme
H2020 COMPET

Project Coordinator
Sofradir (FR)

Partners
AT: EVG
ES: IFAE
FR: ADDL, CEA-IRFU, CEA-Leti, Sofradir

Total budget
€ 1.4 m.

EC Contribution
€ 1.4 m.

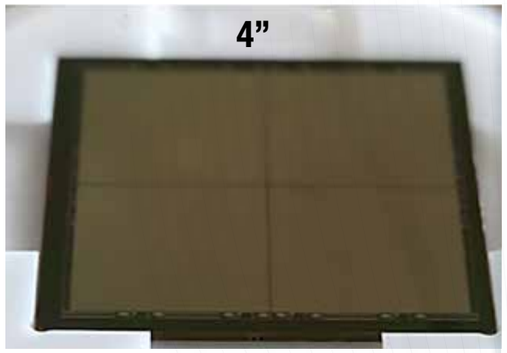
Contract Number
A17-00183

CEA-Leti in ASTEROID

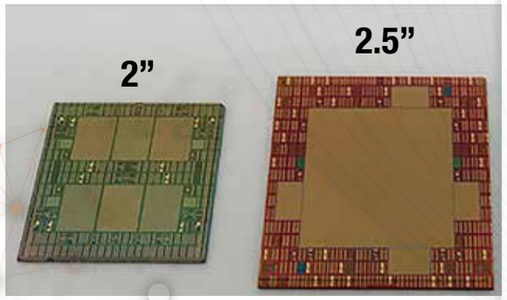
ASTEROID increases CEA-Leti's footprint in the astronomical short-wave infrared detector market. For astronomers, the short-wave range means the band of wavelengths between approximately 2 and 3 µm, which is used for imaging colder objects and in spectroscopy. Close interaction with future customers, including astronomers and optical engineers, has been the starting point for designing and fabricating these state-of-the-art detectors, which are now poised for long-term operation in orbit under very aggressive radiation conditions. The technical resources deployed for their fabrication has had to evolve to meet performance requirements and prepare for the industrialization phase. For the first time at CEA-Leti, very large format arrays (2048 x 2048 pixels at 15 µm pitch) are being fabricated from HgCdTe, an infrared detector material that guarantees best possible performance in relation to noise and quantum efficiency. Fabrication is prompting a variety of technological advances in terms of materials, device fabrication and testing. For example, CEA-Leti has demonstrated, for the first time, Liquid Phase Epitaxial (LPE) growth of HgCdTe on 4" substrates, a size never achieved before. This demonstration of capability has been rapidly matched by CEA-Leti's industrial partner Sofradir and a novel state-of-the-art readout circuit is being designed and built. The first ASTEROID-based focal plane array will be deployed in a ground telescope in Mexico as part of the Sino-French SVOM mission. Shortly, Sofradir intends to build an entirely new production line for these detectors with a view to supplying a major market comprising multiple scientific applications. Lastly, credit must be given to FOCUS, a consortium of French universities that is funding this development and promoting the project's scientific contribution.

Objectives

The ASTEROID project is a scientific and industrial endeavor aimed at developing the high-end, scientific grade infrared detectors needed for astronomical observations. Its principal challenges involve demonstrating the very high performance characteristics required by scientists and manufacturing detectors on a large scale, thereby building European know-how and facilities and training the personnel ultimately needed for scientific ventures. ASTEROID represents a collaborative effort shared by CEA-Leti, Sofradir and three other European partners: Austrian company EVG, French company ADDL and Spanish laboratory IFAE. CEA's Institute for the Study of the Fundamental Laws of the Universe laboratory is also involved.



First demonstration of 4 2048x2048, 15 µm pitch IRFPAs fabricated on a single 4" substrate.
© CEA-Leti



A processed wafer containing 6640x480 FPAs compared to a single 2048x2048 pixel FPA. The difference in size is striking.
© CEA-Leti

IMPACT

The ASTEROID project's impact will be extensive for European business. First and foremost, Europe will achieve a capability for competing with the main US players in this field (Teledyne Inc.), which enjoys the lion's share of the large area, short wave detector market. Its ability to compete in this field will give Europe the necessary strategic independence not only in science and astronomy, but also in other areas such as Earth observation for defense purposes.

Publications

• Review of the development of 2k2 IR FPAs for astronomy and Space in Europe. In Infrared Sensors, Devices, and Applications VIII (Vol. 10766, p. 107660H). International Society for Optics and Photonics. G.Badano, C. Cervera, O. Gravrand, B. Fièque, A. Lamoure, O. Boulade, & S. Mouzali (2018, September).

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• Overview of space activity at Sofradir and new trends for future detector for science applications. In International Conference on Space Optics—ICSO 2016 (Vol. 10562, p. 1056232). International Society for Optics and Photonics. B. Fieque, P. Chorier, N. Jamin, C. Leroy, P. Pidancier, O. Boulade, & O. Gravrand (2017, September).

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Giacomo Badano
giacomo.badano@cea.fr

Pierre Castelein
Pierre.castelein@cea.fr


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BONVOYAGE

http://bonvoyage2020.eu/

Keywords
Communication
Goods
Information centric networking
Internet
Multimodal transport
Network
Network architecture
Nomadic devices
Passengers
Planning
Ticketing
Travel information

BONVOYAGE at a glance

36 months
May 2015 > Apr. 2018

EC Programme
H2020-MG-7.2a-2014
Towards seamless mobility addressing fragmentation in ITS deployment in Europe

Project Coordinator
CNIT (IT)

Partners
AU: Fluidtime
ES: Azkar, Bilbao
FR: CEA-Leti
IT: Consorzio Nazionale Interuniversitario per le Telecomunicazioni, CRAT, Trenitalia
NO: Oslo, Sintef

Total budget
€ 4.0 m.

EC Contribution
€ 4.0 m.

Contract Number
635867

From Bilbao to Oslo, intermodal mobility solutions, interfaces and applications for people and goods, supported by an innovative communication network.

The BONVOYAGE project involves designing, developing and testing a platform for optimizing multimodal door-to-door transport of passengers and goods. The platform integrates travel information, planning and ticketing services by automatically analyzing non-real-time data from heterogeneous databases (on road, railway and urban transport systems), real-time measured data (traffic, weather forecasts), user profiles and user feedback.

CEA-Leti in BONVOYAGE

CEA-Leti has a twofold objective:

• To develop an algorithm for automatically assessing the user transportation mode to define the user modal share (e.g. User A never rides a bike, User B never takes a plane, etc.)

• To develop an algorithm for automatically assessing the user stress level. Transport mode and user stress level are both used for inferring traveler profile in the BONVOYAGE project.

CEA-Leti is working with 2 types of sensor:
• Smartphone sensors for transport mode recognition
• Wearable sensors (Empatica© wristband) to assess the user stress level.

Two Android Apps were delivered at the end of the project: a Mobility Observer and a Stress Observer.

Mobility Observer includes data logging from smartphone sensors with optimized data compression; the algorithm processes the data in real time for recognizing the user transport mode. Transport mode recognition is ensured at a mean performance of 84%, when a GPS signal is used, and of 74% without a GPS signal. Mobility Observer has been optimized to minimize smartphone battery consumption and to be robust to smartphone orientation.

Stress Observer includes connection to an Empatica wristband to acquire the physiological data recorded by this wearable and the algorithm monitoring the user stress level by real time processing of physiological parameters. A calibration step is also included to ensure a user-tailored model for the stress monitoring. Stress Observer therefore takes into account inter-subject variability. Performance of the stress monitoring algorithm has been assessed for real-life recordings from a few traveling subjects. Results have indicated that the mean performance is 96.5% for monitoring user stress level.
In BONVOYAGE project's final step, the functions of user transport mode recognition and stress level monitoring have been embedded in the BONVOYAGE App, which provides a Door-to-Door Journey Planning platform.

Objectives

The BONVOYAGE platform is supported by an innovative information-centric communication network that collects and distributes all the data required. The highly heterogeneous, distributed and mobile nature of data from data centers, sensors, vehicles, goods and people on the move calls for an innovative networking paradigm. Current networks (e.g. Internet) limit themselves to "just" providing communication channels between hosts. Our paradigm, called Internames, allows communications among entities identified by names without the constraint of static binding to a particular location.
The request of a "user" (be it a person or a parcel) to travel from source to destination is managed by the platform with several tools: Metadata Handler collects and elaborates data related to the request and generates a corresponding Context; User Profiler creates a personalized profile, conveying requirements including Quality of Experience parameters and special needs; Multi-Objective Optimizer develops personalized travel instructions, optimal for the Context and User Profile. The user may provide feedback before accepting the travel itinerary. If a trip is not available at the requested time, the user is notified if it becomes available later. An Actuator triggers the necessary services. A Tariff Scheme Designer exploits platform data to define multi-part tariff schemes.
BONVOYAGE trials and demonstrates the platform and communication network in integrated, large-scale, real life application scenarios, incorporated into the normal business operations of our transport operator partners.


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IMPACT

The BONVOYAGE system is based on scalable federated architecture, which clusters national routing services and data sources, and implements Directive 2010/40/EU. A first multimodal door-to-door journey schedule based on a federated infrastructure in Norway, Spain and Italy, was delivered at the end of the project and is open to all transport operators wishing to use the platform. Trenitalia has embedded several BONVOYAGE platform functions in its own App.

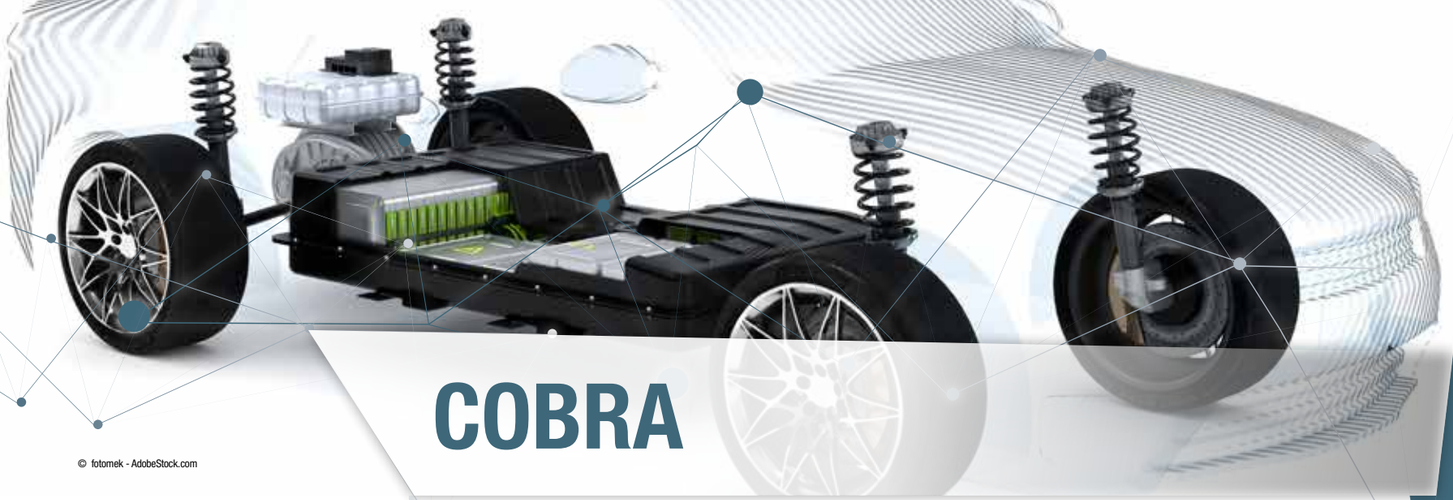
Publications

• *"A Comparison of Wearable and Stationary Sensors for Stress Detection", S. Ollander, Chr. Godin, S. Charbonnier, A. Campagne, SMC2016 IEEE International Conference on Systems, Man, and Cybernetics, 2016, Budapest, October 9-12.*
• *"Feature and Sensor Selection for Detection of Driver Stress", S. Ollander, Chr. Godin, S. Charbonnier, A. Campagne, Third International Conference on Physiological Computing Systems – PhyCS 2016, Lisbon, Portugal, 27th and 28th July 2016.*
• *"Transportation mode recognition based on smartphone embedded sensors for carbon footprint estimation", L. Oana, V. Andrea, 19th International Conference on Intelligent Transportation Systems – IEEE ITSC 2016, Rio de Janeiro, Brazil, 1 - 4 November 2016.*
• *"Real time monitoring of traveller's psychological stress", G. Vila, S. Ollander, Chr. Godin, E. Labyt, S. Charbonnier, A. Campagne, 8th International Congress on Transportation Research - Accepted Paper, 27-29 September 2017, Thessaloniki, Greece.*

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Etienne Labyt
etienne.labyt@cea.fr

Bernard Strée
bernard.stree@cea.fr



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COBRA

COBRA

Keywords
Battery
Embedded electronics
Optical communication
Sensor

COBRA at a glance

48 months
Dec. 2019 > Nov. 2022

EC Programme
H2020 LC-BAT-5-2019: Research and innovation for advanced Li-ion cells (generation 3b)

Project Coordinator
Institut de Recerca en Energia de Catalunya (ES)

Partners
BE: Interuniversitair Micro-Electronica Centrum
DE: Aentron, CARISSMA University, Fraunhofer, Infineon, Liacon
ES: Bax, CIDETEC, Eurecat, IDIADA
FR: CEA-Leti, CEA-Liten, Solvionic
NL: TNO
NO: Ceramic Powder Technology, Resitec
SE: Stockholm University, Uppsala Universitet
TR: AVL

Total budget
€ 11.8 m.

EC Contribution
€ 11.8 m.

Contract Number
875568

CObalt-free Batteries for FutuRe Automotive Applications

The COBRA project involves developing novel Cobalt-free Li-ion battery technology, which overcomes many of the current shortcomings faced by Electric Vehicle (EV) batteries, through holistic enhancement of each battery system component. The goal is to develop a battery system with features including superior energy density, low cost, increased cycles and less critical materials (cobalt). Higher energy density means that such batteries require more efficient, integrated control and status monitoring as well as better understanding of their chemical behavior.

CEA-Leti in COBRA

CEA-Leti's involvement in the COBRA project comprises two main tasks: new sensing functionalities for battery monitoring and digital communication inside the battery pack.

CEA-Leti is tackling the problem of monitoring the battery pack to prevent it failing. Monitoring is currently performed by a set of electronic boards connected to the battery cells on one side and to a central management unit on the other side. These components usually take voltage and temperature measurements, but additional measurements such as current, strain or impedance, can be included. These multiple monitoring signals represent many battery pack internal cables that have to be designed, installed, controlled and maintained. Furthermore, to ensure optimum monitoring of ever denser lithium cells, the number of cell-based sensors will need to increase to guarantee an acceptable safety level. If all these sensors were to be connected by cables to the electronic management units, this would represent a loss of mass energy density at battery pack level.

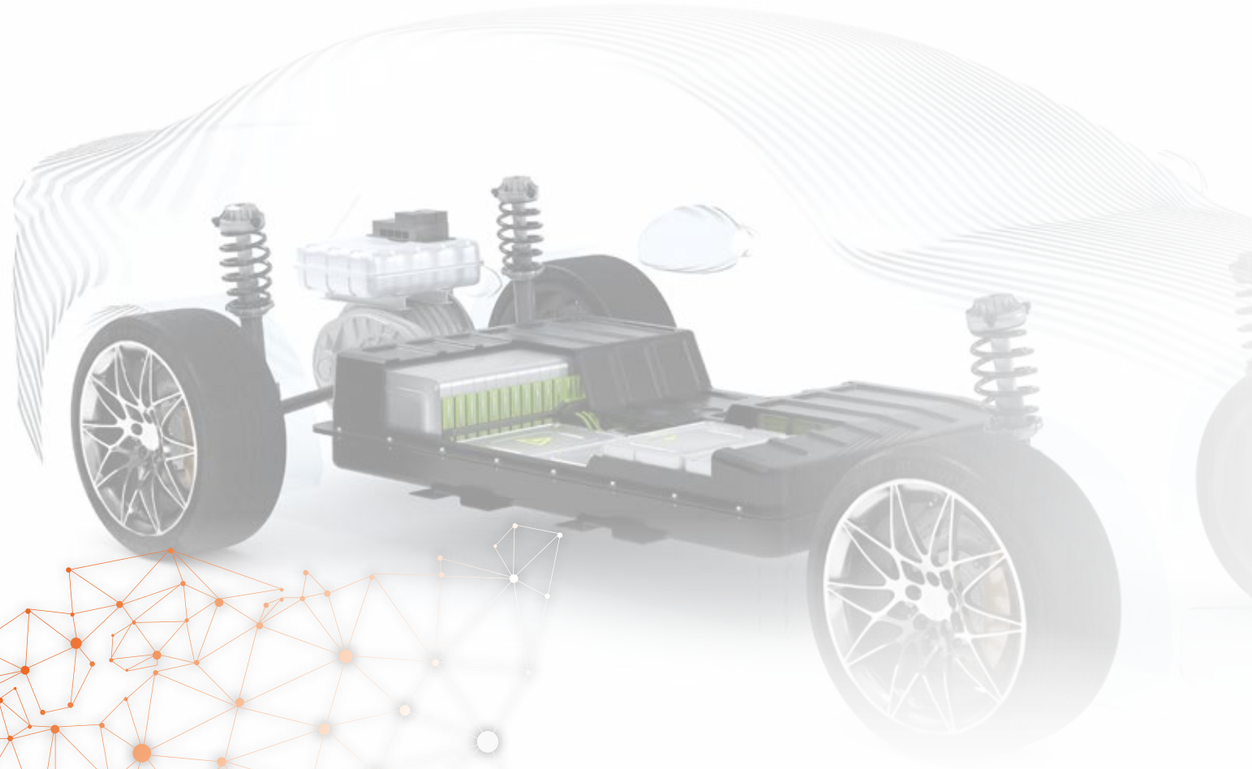
CEA-Leti's first objective in COBRA is therefore to develop an architecture, in which each cell is associated with a small electronic circuit embedding sensing capabilities, closely connected to the cell and communicating wirelessly with the central management unit. The Institute will develop an asynchronous, robust, distributed and multiplexed optical communication system that can be integrated into low-cost, very low-power electronics.

Secondly, CEA-Leti is addressing the problem of battery critical failure monitoring through investigation of a new monitoring device: a gas sensor. Failure of a battery element is generally accompanied by emission of volatile chemicals due to degeneration. Detecting these emissions at earliest stage would prevent deep damage of critical battery elements. A sensor for measuring these VOCs in real time is therefore of prime importance.

The objective is therefore to develop a sensor suitable for detecting target chemicals that indicate battery pack status and possible degradation.

Objectives

The outcome of the COBRA project will be a unique battery system that merges several sought-after features including higher energy density, low cost, increased cycles and less critical materials. To achieve these ambitious objectives the project team will upgrade electrochemical performance by focusing on a Co-free cathode and an advanced Si composite anode and electrolyte/separator. It will develop cell manufacturing and testing for electrical and electrochemical performance, leverage the use of smart sensors and advanced communication to optimize the system control, and ensure battery pack manufacturing that delivers cost effectiveness and environmental sustainability over the battery's lifetime. The proposed Li-ion battery technology will be demonstrated at TRL6 (battery pack) and validated on an automotive EV testbed. The involvement of several leading battery manufacturers will ensure easy adaptation to production lines and scale-up. This will contribute to higher market adoption, while helping to strengthen Europe's position in the field. The project is enjoying the participation of three universities, seven RTOs, four SMEs and five manufacturers, thereby covering the entire value chain and strongly committing the EU battery industry.



IMPACT

The COBRA project aims to improve all aspects of batteries and to develop competitive battery technology based on performance, cost and an environmental and social perspective. Apart from eliminating cobalt in the electrode, COBRA proposes 50% increase in existing EV battery energy density and a reduction in battery CO2 footprint by decreasing primary material in favor of recycled material. Moreover, COBRA targets a 50% reduction in the battery pack price to improve the competitiveness of the European battery industry.

TRL
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Vincent Heiries
vincent.heiries@cea.fr

Bernard Strée
bernard.stree@cea.fr



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CONVERGENCE

https://convergence-era.org/

Keywords
Activity sensors
Bio-sensors (sweat and breath)
Environmental (gas and particle) sensors
Energy harvesting
Flexible electronics
Heterogeneous integration on flex
Internet of Things
Low power wearable sensors
Preventive healthcare
Wearable

CONVERGENCE at a glance

36 months
May 2017 > Apr. 2020

EC Programme
FLAG-ERA JTC 2016

Project Coordinator
EPFL (CH)

Partners
BE: UCL
CH: ETHZ, HCC
EE: TTU
FR: CEA-Leti, G-INP, STM
IT: ENEA, IUNET, UCBM, UNICA, TAGLIAFERRI
LV: EDI
RO: IMT, UTBV
TR: METU

Total budget
€ 2.5 m.

EC Contribution
national funding

Contract Number
ANR-16-PILO-0003-07

Frictionless Energy Efficient Convergent Wearables For Healthcare and Lifestyle Applications

CONVERGENCE is an innovative project focusing on development of wearable platforms dedicated to preventive lifestyle and healthcare and for environmental monitoring. A platform is a system compatible with different energy harvesting sources and selected sensors, typically bio, gas and activity detectors, which communicate using Bluetooth low energy.

CEA-Leti in CONVERGENCE

CEA-Leti's main contribution to the CONVERGENCE project is development of demonstration platforms for wearable IoT flexible systems, which are compatible with sensors and energy harvester modules developed by the consortium partners.
The aim is to create a wireless and multifunctional wearable system able to monitor not only personal physical condition (physical activity, core body temperature, electrolytes and biomarkers), but also the environment (chemical composition of the ambient air).
> Convergence of technologies into smart sensing systems driven by lifestyle and healthcare applications.

Achievements after 18 months

• Development of sensors and energy harvester platforms on a rigid substrate with:
- First version design and fabrication
- Bluetooth Low Energy communication and data collection on mobile phone
- Compatibility with different types of sensors and energy harvesting sources.

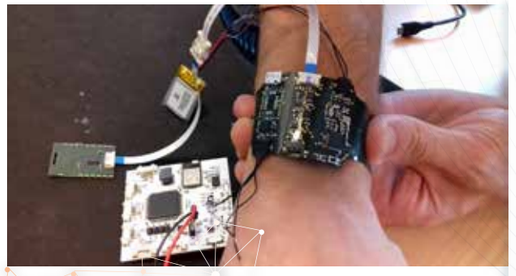
• Development of sensor platforms compatible with:
- Gas sensors
- Temperature sensors
- Activity sensors
- Nano-power energy harvesting ASIC module.

• Energy harvester platforms compatible with PV cells and mechanical energy harvesters (piezoelectric, electromagnetic, electret-based, triboelectric).

• Successful laboratory testing.

Objectives

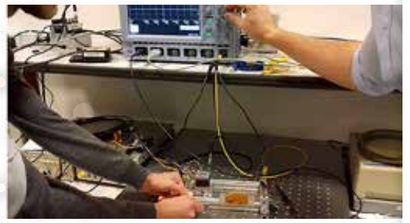
Emergence and deployment of the Internet of Things and the Trillion-of-Sensors Planet depends on advanced concepts such as zero-power, intelligent, autonomous systems featuring energy efficient sensing, computation and communication. The science of zero-power has indicated exploratory research needs involving novel materials, devices and system architectures that could prompt energy savings by a factor of up to 1000x for processing the useful bit of information. Energy efficient technologies of this type have been envisaged in combination with smart, multiple harvesting interfaces, capable of detecting and adapting to most suitable energy sources, thereby leading to harvester energy output improvements by a factor of 100x.
In CONVERGENCE, we have adopted a more focused strategy centered on proofs of concept involving energy efficient sensor networks for future wearables, which exploit the convergence of multi-parameter biosensors and environmental sensors on an autonomous system technology platform serving data fusion for preventive lifestyle and healthcare. The project interconnects solidly a critical mass of research institutions and end users to establish the foundations of a future emerging European research project in this field by linking national competences and resources.
The choice of wearables for preventive strategies is due to health and care service failure to grow with modern society's demographic shift and lifestyle-related diseases. Given the strong pressures on the healthcare system, one solution could be to 'shift the curve' from high-cost, reactive, bed-based care to preventive, proactive care implementing energy efficient wearable technologies.
The smart systems proposed by CONVERGENCE are foreseen as wearable, wirelessly interconnected, smart, hardware embodiments enabled by energy-efficient technologies, which can meet the demands of lifestyle and medical applications in terms of autonomy in the virtually continuous collection of data for early detection strategies. These systems will certainly become a part of the Internet of Things (IoT) and the related services for Quality-of-Life and/or paradigm shifts in the medical field. More recently, this concept has developed into the so-called Internet of Everything (IoE), which is a catch-all phrase to describe adding connectivity and intelligence to almost every device to provide special functions. The expected innovation outputs in IoE technologies for healthcare and lifestyle are very high: they require interaction of multidisciplinary teams such as the one performing the CONVERGENCE project.
In the CONVERGENCE-based approach, part of the information processing and storage could be local, while another part could be communicated and processed in the cloud, depending on the application scenario. This would empower the user with decisions imposing a high level of data privacy and security. The associated data collection and data analytics of the CONVERGENCE systems are expected to enable personalized advice and assistance related to health and interaction with the environment that extend beyond today's wireless sensor networks. Proofs of concept centered on wrist devices and smart patch wearables with multiple convergent sensors will offer unique solutions for new generations of non-invasive, virtually continuous healthcare applications. In the long term, they are expected to form the basis of future generations of human-machine interfaces with capabilities unforeseen today.



Flexible sensor platform (with onboard IMU sensor) tested with gas and activity sensors.
© CEA-Leti



© a) CEA-Leti



© b) CEA-Leti done at G-INP

Rigid energy harvester platform tested with a) PV cells b) piezoelectric generator.

IMPACT

Knowledge development concerning flexible integration and wearable sensing technology.

Publications

• «Bluetooth Low Energy throughput in densely deployed radio environment», A. Ancans, J. Ormanis, R. Cacurs, M. Greitans, E. Saoutieff, A. Faucon, IEEE, 23rd International Conference Electronics, Lithuania, June 2019.
• «Sensor and Energy Harvesting flexible platform», E. Saoutieff, A. Faucon, S. Boisseau, T.Ernst, ESSDERC/ESSCIRC conference, NEREID-SINANO-Workshop «Nanoelectronics and Smart System Technologies for Future applications», Dresden, Germany, September 2018.
• «Sensors platform for health and environmental monitoring», E. Saoutieff, A. Faucon, S. Boisseau, T. Polichetti, M.L. Miglietta, B. Alfano, E. Massera, S. De Vito, S. Petre, T. Walewyns, N. André, D. Flandre, C. Moldovan, M. Greitans, Semi-Conducting Nanomaterials for Health, Environment and Security Applicccations, Workshop Nano2sence, Grenoble, France, November 2018.
• «Sensors and related devices for IoT, medicine and smart-living», T. Ernst, R. Guillemaud, P. Mailley, J.P. Polizzi, A. Koenig, S. Boisseau, E. Pauliac-Vaujour, C. Plantier, G. Delapierre, E. Saoutieff, R. Gerbelot-Barillon, E. Calvanese Strinati, S. Hentz, E. Colinet, O. Thomas, P. Boisseau, and P. Jallon, VLSI, Honolulu, USA, June 2018.
• «A networked wearable device for chemical multisensing», T. Polichetti, M.L. Miglietta, B. Alfano, E. Massera, S. De Vito, G. Di Francia, A. Faucon , E. Saoutieff, S. Boisseau, T. Walewyns, N. Marchand, L. A. Francis, 4° Convegno Nazionale Sensori, Italia, February 2018.

TRL
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Elise Saoutieff
elise.saoutieff@cea.fr

Bernard Strée
bernard.stree@cea.fr


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Enlightened

Keywords
Mass spectrometry
NEMS
Optomechanics
Resonators

Enlightened at a glance

72 months
Jun. 2014 > May 2020

EC Programme
ERC Consolidator

Project Coordinator
CEA-Leti (FR)

Partners
NA

Total budget
€ 2 m.

EC Contribution
€ 2 m.

Contract Number
616251

Nanophotonic Nanomechanical Mass Spectrometry for Biology and Health

The ENLIGHTENED project is devising a system to analyze the mass distribution of species that are today out of the reach of any commercial instrument. A new system architecture will be demonstrated with new optomechanical resonators for mass sensing. This will reveal new physics governing noise limitation at the nanoscale.

CEA-Leti in Enlightened

For the first time, ENLIGHTENED has shown that the model of resonator frequency stability commonly accepted by the community is erroneous for silicon NEMS resonators.

We have also demonstrated that our system could perform mass measurements efficiently in a mass range outside the range of any commercial instrument. This was shown using the highest molecular mass ever measured: a bacteriophage virus capsid.

We have performed the first single-particle mass spectrometry analysis with optomechanical resonators.

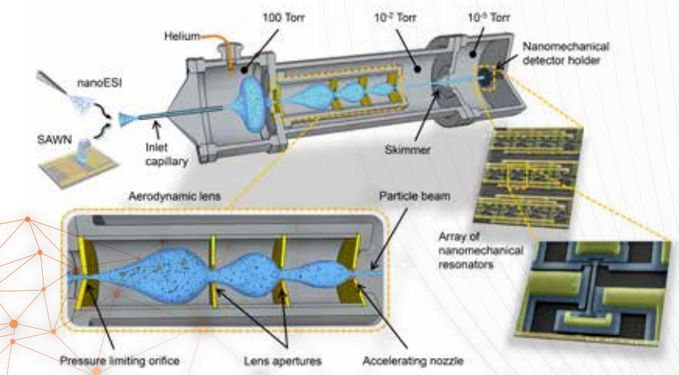
Objectives

Mass spectrometry has become a routinely used analytical tool in modern biological research and has gained a foothood in recent years in the realm of clinical diagnostic and screening. However, it the technique remains expensive and complex, and it cannot analyze biomolecules heavier than a few Mda because its principle depends on ionization. Furthermore, it cannot characterize the genetic diversity of such heavy entities because it averages more than 100 million particles per measurement.

Building on nanomechanical mass sensing, ENLIGHTENED aims to demonstrate a breakthrough mass spectrometry concept for intact biomolecules in a so far unexplored high mass range based on single molecule sensitivity and unprecedented resolving power.

ENLIGHTENED objectives:
- Demonstration of a novel system architecture for transferring all single mass neutral particles to the detector in a focused beam
- Development of a new class of nanomechanical mass detectors with close-to-100% capture cross sections. These detectors are ultra-dense arrays of resonating devices, which are coupled to photonic resonators ensuring efficient transduction, large scale multiplexing, high frequency operation and single mass self-oscillation
- Understanding and suppressing the limiting source of frequency noise to improve the mass limit of detection of nanomechanical devices by orders of magnitude
- Demonstrating the full potential of this breakthrough technology by acquiring the mass spectra of high-mass bioparticles never anaylzed before. Those bioparticles were selected with reference to a number of biological and clinical issues.

ENLIGHTENED uses photons to shed light on unexplored high mass species on an individual level; this is of major biomedical significance and will expand our understanding of simple life forms.



High-transmission system architecture for nanomechanical resonator-based charge-independent single particle mass sensing. The setup consists of three chambers with decreasing pressures. Analytes in solution are nebulized by SAWN or nano-ESI, and aspirated through a heated metal capillary inlet at atmospheric pressure. An aerodynamic lens focuses the particle stream (shaded blue area) which is then transferred onto an array of frequency-addressed nanomechanical resonators.
© CEA-Leti

IMPACT

ENLIGHTENED has enabled the EU to pioneer NEMS-based Mass Spectrometry systems for biology and the biotech industry.

Publications

- *Nat. Commun. 2018, (2018) 9:3283, E. Sage, M. Sansa, S. Fostner, M. Defoort, M. Gély, A.-K. Naik, E. Colinet, C. Masselon, A. Brenac, S. Hentz.*
- *Nat. Nanotechnol. 2016, 1–31, M. Sansa, E. Sage, E.-C. Bullard, M. Gély, T. Alava, E. Colinet, K. Naik, L.-G. Villanueva, L. Duraffourg, M.-L. Roukes, S. Hentz.*
- *S. Dominguez-Medina, S. Fostner, M. Defoort, M. Sansa, A.-K. Stark, M.-A. Halim, E. Vernhes, M. Gely, G. Jourdan, T. Alava, P. Boulanger, C. Masselon, S. Hentz, S. Science (80-.) 2018, 362 (6417), 918–922.*

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Sébastien Hentz
sebastien.hentz@cea.fr

Yves Quéré
yves.quere@cea.fr



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EuroPAT-MASIP

European Packaging, Assembly and Test Pilot for Manufacturing of Advanced System-in-Package

The EuroPAT-MASIP project is intended to strengthen the European ecosystem in microelectronics and more specifically in advanced packaging (FOWLP) by developing new technologies and accelerating their transfer to mass volume production. Six separate pilot applications have been allocated to the project consortium members. In particular, they target automotive components such as inertial sensors, tire pressure sensors, image sensors, silicon photo-multipliers, RF transmitters and radar systems.

https://ipexternal:4444/sites/EuroPATMASIP/

Keywords

Embedded systems
Embedded Wafer Level Ball Grid Array (eWLB)
Fan-Out Wafer-Level Packaging (FOWLP)
Micro (system) engineering
Packaging
Simulation and design tools
System In Package (SIP)
Systems Engineering and Integrated Systems Design

EuroPAT-MASIP at a glance

36 months
Avr. 2017 > Avr. 2020

EC Programme
ECSEL

Project Coordinator
Amkor formerly Nanium S.A. (PO)

Partners
AT: BESI AT, EVG
DE: AMIC, Elmos, FhG, KETEK, InnoSenT, NANOTEST, PacTech, RoodMicrotec, Silicon Radar, TexEDA
FI: Afore, NT, MAS, Murata, SPV, VTT
FR: CEA-Leti, NXP FR, P-SiP, Valeo, 3DiS
HU: SEMILAB
NL: BESI NL, Sencio
PT: NANIUM
SE: Advanced Vacuum

Total budget
€ 29 m.

EC Contribution
€ 7.2 m.

Contract Number
737497-2

Objectives

The EuroPAT-MASIP project reinforces Europe's semiconductor manufacturing position by focusing on the semiconductor and MEMS packaging ecosystem. Semiconductor packaging, assembly and testing involve most of the semiconductor value chain, ranging from material suppliers through software design and packaging foundries to test houses. EuroPAT-MASIP consolidates and extends the continent's leadership in semiconductor processing know-how by developing and fostering packaging-related technological and manufacturing building blocks for different (emerging) industrial sectors through:

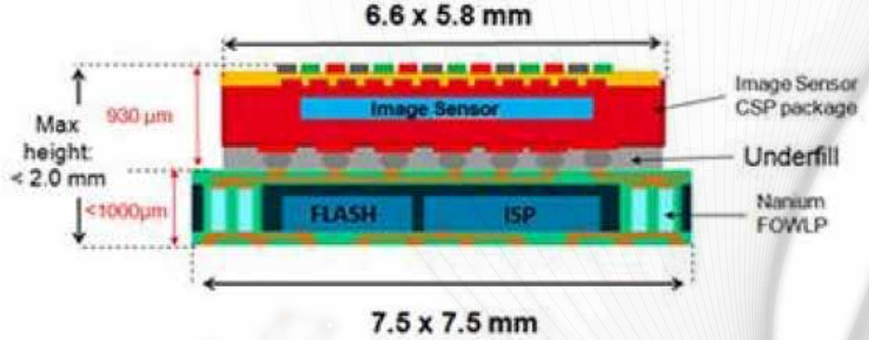
- Modelling, design and simulation of key packaging-related features and challenges
- Developing key packaging technologies, equipment and materials
- Heterogeneous (3D) integration of smart system building blocks (More-than-Moore, MtM) and System in Package (SIP)
- Establishing testing strategy including metrology, methods and equipment, reliability and failure analysis.

The project is accelerating manufacturing uptake of new technologies and is curtailing time to market by demonstrating industrial need-based application pilots with new capabilities. The automotive application pilots embody manufacturing science, are based on the industrial partner's needs and capabilities, and are therefore industry compatible.

EuroPAT-MASIP is striving to increase the competitiveness and the global market share of the European semiconductor industry by fostering the competence and capabilities of semiconductor packaging. Actions are being implemented to facilitate cooperation of European semiconductor and MEMS packaging ecosystems to ensure joint network creation on completion of the project. The EuroPAT-MASIP consortium actively promotes capabilities and related ecosystems to attract talent and tackle academic issues. The project outcomes will ultimately enhance the technological attractiveness for private investment and talent by developing and promoting the key capabilities to match the future needs of European industries and emerging technology stakeholders.

CEA-Leti in EuroPAT-MASIP

Main CEA-Leti outcomes, through its active participation in a major European consortium of the most prominent companies in the field, include development of advanced packaging technologies such as fan-out wafer level packaging. CEA-Leti is contributing its expertise in designing and assembling the highly reliable Systems in Package (SiP) modules required for automotive applications. Working closely with industrial end-users and packaging house partners in building an operational SiP camera module, the ambition is to raise technological readiness for transfer to industry (TRL 4).



SIP automotive camera module concept using FOWLP technology and flip chip CIS stacking.
© CEA-Leti

IMPACT

The main impact of the project is its strengthening of European partner cooperation in building an operational ecosystem and accelerating re-industrialization in advanced packaging technologies.

TRL
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Gabriel Parel
gabriel.pares@cea.fr



EVERLASTING

EVERLASTING

https://esites.vito.be/sites/everlasting/default.aspx

Keywords
Battery management system
Battery modelisation
Li-Ion battery
Thermal runaway detection

EVERLASTING at a glance

48 months
Sept. 2016 > Sept. 2020

EC Programme
HORIZON 2020 - GV8-2015
type of action : Research and Innovation Action

Project Coordinator
VITO (BE)

Partners
BE: Vlaamse Instelling voor Technologisch Onderzoek N.V.
DE: Lion Smart GmbH, Rheinisch-Westfaelische Technische Hochschule Aachen, Technische Universitaet Muenchen, TUV Sud Battery Testing GmbH
FR: CEA, Siemens Industry Software SAS
IL: Algolion LTD
NL: Technische Universiteit Eindhoven, VDL Bus & Coach BV
SK: GreenWay Operator a.s.

Total budget
€ 8.2 m.

EC Contribution
€ 8.2 m.

Contract Number
713771

Electric Vehicle Enhanced Range, Lifetime And Safety Through INGenious battery management

The EVERLASTING project is developing innovative technologies to improve the reliability, life and safety of lithium-ion batteries mainly for electric vehicles by developing more accurate and standardized battery monitoring and management systems. The work performed in this project will make it possible to predict battery behavior in all circumstances and throughout battery life. This will enable optimized battery management ensuring greater reliability and security.
The outcomes of this project will maintain the battery in a safe, optimum operating condition to prolong its life and autonomy.

Objectives

Batteries are not yet the ideal energy containers they were promised to be; they tend to be expensive, fragile and potentially dangerous. Moreover, the current EV cannot yet compete yet with thermal energy-based vehicles in terms of driving range and flexibility. The EVERLASTING project is intended to bring Li-ion batteries closer to ideal by focusing on the following technological areas.
• Predicting battery system behavior in all circumstances and throughout battery life. This will allow accurate dimensioning and choice of correct battery type, leading to lower cost. It will also facilitate development of a powerful battery management system at all stages of development from concept to fully tested product.
• Sensing signals in addition to standard current, voltage and temperature parameters. This multi-sensing approach will provide more varied, in-depth data on battery status, thereby facilitating pro-active, effective battery management to prevent issues rather than mitigate them.
• Monitoring battery status by interpreting rich sensor data. Intelligent combination of this information with road, vehicle and driver data will allow us to offer accurate higher-level driver feedback. This induces greater trust and hence a less driving range-related anxiety.
• Managing the battery in a proactive way based on correct assessment of its status. Efficient thermal management and load management results in greater reliability and safety and leads to lower overall cost throughout a longer battery life.
• Defining standard BMS architecture and interfaces and gathering the required market support. This will allow a standard BMS component industry to flourish and will result in lower cost.

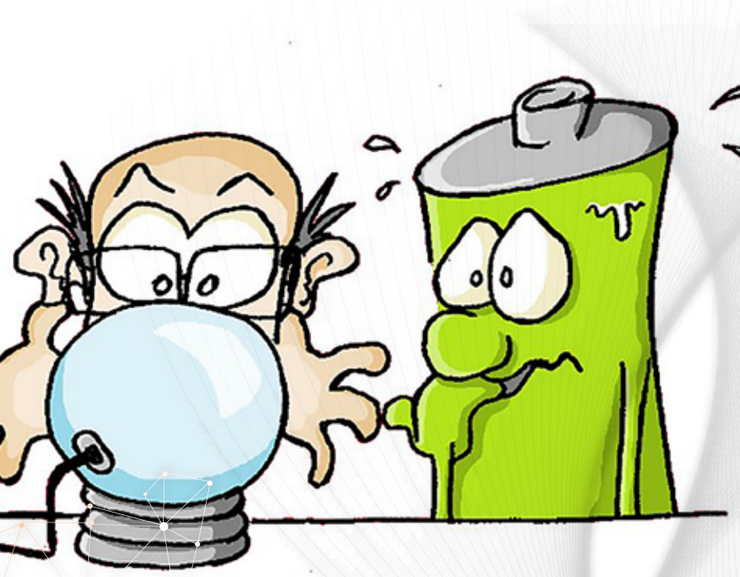
CEA-Leti in EVERLASTING

Greater knowledge of on-line battery cell degradation measurement by advanced sensing and analysis based on cutting-edge mathematical methods and improved thermal and electrical battery models have been achieved.

Advantageous progress has also been made regarding reducing orders of battery cell models, allow a trade-off between accuracy and computational complexity.

Development of a multi-physical sensor network deployed around the battery cell, enabling very efficient, robust cell monitoring. The different types of characteristic signals from the monitored cell (electrical sensors, thermal sensors, mechanical sensors, acoustic sensors) allow cell state of safety to be accurately estimated. The developed system permits faster detection and more accurate prediction of safety hazards; this could induce proactive and reactive safety management implementing corrective actions to prevent fires, which have cost M€s in damages, caused personal injuries and in some instances fatalities.

CEA-Leti has designed new predictive intelligence algorithms within the framework of these battery cells fully equipped with specific sensors. These establish proper conditions for efficient warning, correction and intervention in relation to major, recurrent and minor safety hazards by introducing a new concept based on safety domains and time constants. The performance achieved by the cell State of Safety estimation system developed by CEA-Leti allows one to expect to better usage and even extension of battery cell Safe Operating Area and, ultimately, greater autonomy at constant cost.



Predicting battery state.
© CEA-Leti

IMPACT

The EVERLASTING project extends our knowledge of Li-Ion battery cells and the phenomena at work during operation both on a system scale and on electrochemical scale.
CEA-Leti's research involving cell monitoring has been particularly thorough. The work on cell monitoring using the multi-physical sensor network will allow us to progress further towards Smart Cell technologies and ensure leadership in battery management.

TRL
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Vincent Heiries
vincent.heiries@cea.fr

Bernard Strée
bernard.stree@cea.fr



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GATEONE

Innovation Service for European Smartization by SMEs

Access a unique portfolio of smart solutions. Intelligent systems, high connectivity, autonomous systems… GATEONE offers solutions to European SMEs. Demonstrators meeting SME requirements are submitted for assessment.

gateone PROJECT

http://www.GATEONE.eu

Keywords
Demonstrator
Innovation
Internet of Things (IoT)
RTO
Smart system
SME

GATEONE at a glance

42 months
Jan. 2015 > Jun. 2018

EC Programme
H2020 ICT-02-2014
Smart System Integration
https://smartanythingeverywhere.eu/

Project Coordinator
CEA-Leti (FR)

Partners
CH: CSEM
DE: Fraunhofer IPMS
ES: Ikerlan-IK4
FI: VTT Technical Research Centre of Finland
FR: Blumorpho, LAAS-
Centre National de la Recherche Scientifique
IE: Cork, National University of Ireland,
University College Cork
UK: University of Teesside

Total budget
€ 6.7 m.

EC Contribution
€ 5.4 m.

Contract Number
644856

Objectives

FREE DEMONSTRATOR ASSESSMENT PROGRAM for SMEs
The objective of GATEONE is to accelerate smart system adoption by European SMEs by facilitating their access to advanced technologies for developing innovative, smart solutions.
GATEONE offers «Innovation as a Service» to assist SMEs in structuring a complete, specific innovation chain for:
- Demonstrating the strength of smart system Key Enabling Technologies to create sustainable differentiation on their market
- Encouraging SME commitment to radical, disruptive innovation using a «technology push» approach to consolidate a business case
- Generating innovation opportunities for SMEs, while reducing and managing their investment risk:
  - GATEONE enables state-of-the-art technology assessment by SMEs based on free demonstrators
  - GATEONE ensures introduction to potential production partners, when required.

GATEONE has the vision to make smart system technologies accessible as solutions to non-expert SMEs (newcomers to investment in smart systems technologies) and traditional European industries, which are unfamiliar with smart systems or innovation.
GATEONE aims to position SMEs as key players of European industry smartization, thereby strengthening European competitiveness.
This innovation action generates a structured dialogue through concrete cooperation between the research community (research centers and academics) and SMEs.

GATEONE contributes to defining best practices at pan-European level along with a sustainable RTO and SME cooperation framework.

CEA-Leti in GATEONE

Strong leverage effect:
CEA-Leti has produced 14 prototypes with values ranging from 50 to 100 k€. One or more SME or manufacturer in the value chain has been involved, when it could assist in application assessment. In all, over 25 SMEs have joined CEA-Leti in defining and assessing the market for these prototypes, over 10 of which have progressed to the second "Gate-two" development step.

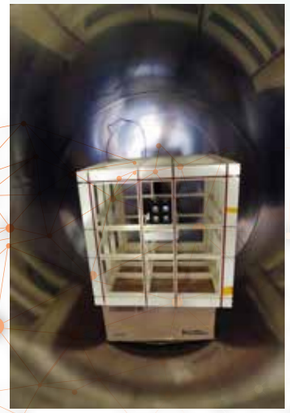
The leverage effect of CEA-Leti prototypes is 2.5 times over 2 years with 2.4 M€ generated for 975 k€ invested by the EU.

Concrete results: 2 start-up creations

• MOOVLAB was created in 2016 with the two SMEs involved in GATEONE. European funding helped to design the first bricks of the wearable gym motion tracker used today by the start-up. The MOOVLAB platform was presented at CES 2017 and 2018 (http://www.cea.fr/english/Pages/resources/videos/startup-moovlab.aspx). MOOVLAB generated its first turnover in 2017 by developing its first sport escape game, "Escape to Mars", for KeepCool (2nd gym operator in France). The start-up is now developing an interactive workout training video for gyms and is seeking funds for industrializing and commercializing its solution at gyms and companies in Europe.

• Magnetoencephalography (MEG) is an imaging technique that measures brain activity based on magnetic field measurements. The prototype is based on low noise magnetometers operating at room temperature. GATEONE has enabled a first demonstration with a single sensor offering higher sensitivity of 60 fT/rtHz. R&D projects were subsequently launched with a medical team and a Carnot institute; these produced a 30% increase in sensitivity and enabled a 5 sensors prototype to be designed. Clinical trials are planned to test the demonstrator for epilepsy at the start of 2020. The team has join CEA-Leti's incubator for creating an MEG company mid-2020.


MEG casque-final.
© MEG


MEG proto capteur.
© MEG


© Moovlab


MOOVLAB sensor.
© Moovlab

IMPACT

In all, GATEONE has delivered 50 demonstrators and 24 SMEs have adopted the technology in their development roadmaps. 22 companies have sealed partnerships for Gate-two projects either through bilateral contracts with the RTO or under grant. For 2.875M€ invested in the demonstrator activity, 6.2M€ was generated by Gate-two projects in 2017-2018 (2.1 times leverage). Some projects have already led to revenue generation by SMEs.

Publications
- *"Best Early Stage Innovation", MEG demonstrators wons the Innovation Radar Prize 2017 @ European Commission ICT proposers' day 2017, Budapest.*
- *"The GATEONE: a digital innovation hub accelerating innovation through ecosystem design and product trajectory." R. Hamelin, G. Andrieux, I. Chartier, B. Roustom, Th. Healy, Z. Ali, B. Legrand, K. Mayora, M. Scholles, R. Guerre. Smart Systems Integration 2018; 12th International Conference and Exhibition on Integration Issues of Miniaturized Systems: Smart Systems Integration 2018 - Dresden, Germany*
- *Consumer Electronic Show (CES 2017 and 2018, Las Vegas), with Moovlab and APNEA Band.*

TRL
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Isabelle Chartier
isabelle.chartier@cea.fr

Bernard Strée
bernard.stree@cea.fr



HADRIAN

HADRIAN
Holistic Approach for Driver Role Integration and Automation Allocation for European Mobility Needs

Keywords
Autonomous driving
Autonomous vehicle
Driver monitoring
Human machine interface

HADRIAN at a glance

48 months
Dec. 2019 > Nov. 2022

EC PROGRAMME
H2020 DT-ART-03-2019: Human centred design for the new driver role in highly automated vehicles

PROJECT COORDINATOR
VIF (AT)

PARTNERS
AT: ASF, AVL, IESTA, PLUS
DE: BAST, RTWH Aachen, VDI/VDE
ES: Tecnalia, Universidad de Granada
FR: CEA-Leti
GR: NTUA
NL: TU Delft
SI: NERVTECH
TR: Ford
UK: University of Surrey

TOTAL BUDGET
€ 7.9 m.

EC CONTRIBUTION
€ 7.9 m.

CONTRACT NUMBER
875597

Holistic Approach for Driver Role Integration and Automation Allocation for European Mobility Needs

The driver of a vehicle in highly automated driving mode may adopt different behaviors. The HADRIAN project is developing solutions to ensure safe transition between use cases at different automation levels and that drivers maintain a very clear understanding of the degree of automation enabled in each situation.

CEA-Leti in HADRIAN

CEA-Leti is developing a new model called FIT2Drive, which provides information on driver ability to resume driving. This applies to vehicles at autonomy level 2 (partial automation options available – vehicle can control speed and steering wheel in specific conditions) to level 4 (high automation – autonomous vehicle can handle most normal driving tasks on its own, but will still require driver intervention from time to time, e.g. during poor weather conditions or other unusual environments). CEA-Leti is focusing on:

• Selecting relevant sensors such as wearables as references for physiological sensing (e.g. wristband/smartwatch, smartphones, headset, etc.) and nearables in the cab (sensing devices in a person's close environment but not worn by the person – e.g. a eye-tracking device)

• Defining data collection based on a driving simulator through measurement campaigns

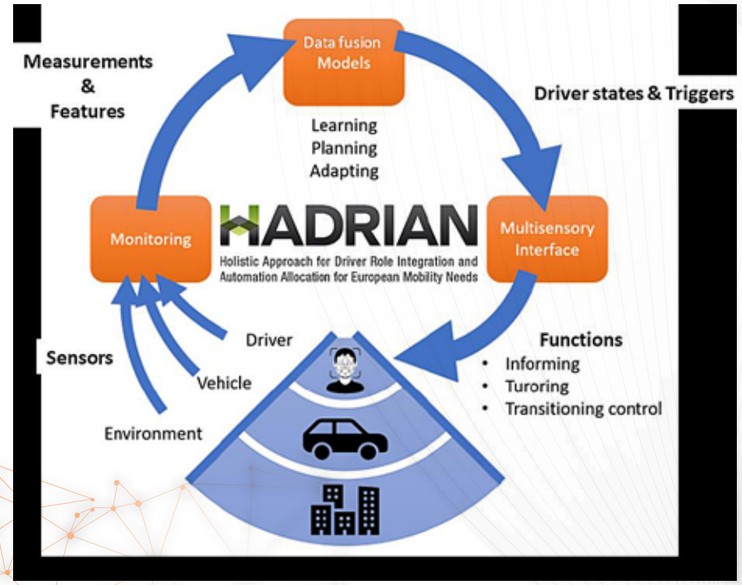
• Sensor data cleaning

• Developing the FIT2Drive algorithm (off-line and on-line) integrating actuators (e.g. sound, light, vibrations, etc.), if possible. Actuation can be an essential part of driving operations by contributing to driver fitness (or if the driver provides no relevant response in terms of acting to produce safe vehicle action)

• Integrating the model for demonstration activity in a simulator and a vehicle.

Objectives

The HADRIAN project represents a human-centered revolution in defining driver roles in Automated Driving (AD), starting with human mobility requirements within the larger framework of Europe's future mobility visions in the areas of shared, personal and freight mobility. Holistic driving system solutions are being conceptualized based on realistic combinations of vehicle and infrastructure capabilities matched with human capabilities to achieve safe, acceptable and trustworthy use of AD functionality and transitions between AD levels.
The project focuses on the usefulness of dynamically adjusting (fluidifying) human machine interfaces (HMI) that take environmental and driver conditions into account for providing adaptive signals, information or transfer authority required by the driver for safe transition between AD levels. Real-time driver status models, novel sensor and information fusion methods and algorithms, and decision logic algorithms for contextually sensitive interventions and information offers will be developed to achieve fluid HMI (f-HMI). A fluid tutoring system will provide stepwise driver training and enable calibrated levels of trust.
Furthermore, the project aims to increase the safety of AD level transitions by 85% with respect to traditional, non-adaptive HMIs and to achieve an acceptability of 95%. Nineteen human subject studies, covering a broad range of driver demographic and cultural factors, will explore and evaluate f-HMI concepts and driver monitoring methods in driving simulators and field demonstrations. Field demonstrations will be performed using the full range of light to larger passenger vehicles and freight vehicles/trucks (Classes L, M, and N).
Ultimately, the HADRIAN demonstrators and effectiveness metrics will be translated into guidelines and recommendations for OEMs worldwide to ensure integration of safe, acceptable and trustworthy AD technologies and functionalities into human-machine systems.



© HADRIAN

IMPACT

• To extend knowledge on physiological sensing in the driver's cab.

• To provide a new estimator of a Fit2Drive indicator based on physiological sensing of the driver and artificial intelligence modeling.

• To transfer and exploit the model with automotive partners.

TRL
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Viviane Cattin
viviane.cattin@cea.fr

Bernard Strée
bernard.stree@cea.fr


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iCspec

In-line Cascade laser spectrometer for process control

The iCspec project aims to develop compact, robust, maintenance-free sensors for oil refinery process control to optimize the refinery processes and reduce related pollution.

www.icspec.eu

Keywords
Gas analyser
ICL-array
Mid infrared
QCL-array
Spectroscopy

iCspec at a glance

36 months
Apr. 2015 - Mar. 2018

EC Programme
H2020 SPIRE-01-2014 - Integrated Process Control

Project Coordinator
Siemens (GE)

Partners
FR: CEA-Leti, III-V Lab, Mirsense
GE: Julius-Maximilians Universitaet Wurzburg, Nanoplus Nanosystems and Technologies Gmbh
PL: Airoptic Spolza Z Ograniczonaodpowiedzianoscia, Politechnika Wroclawska
SE: Preem Aktiebolag

Total budget
€ 5.5 m.

EC Contribution
€ 5.5 m.

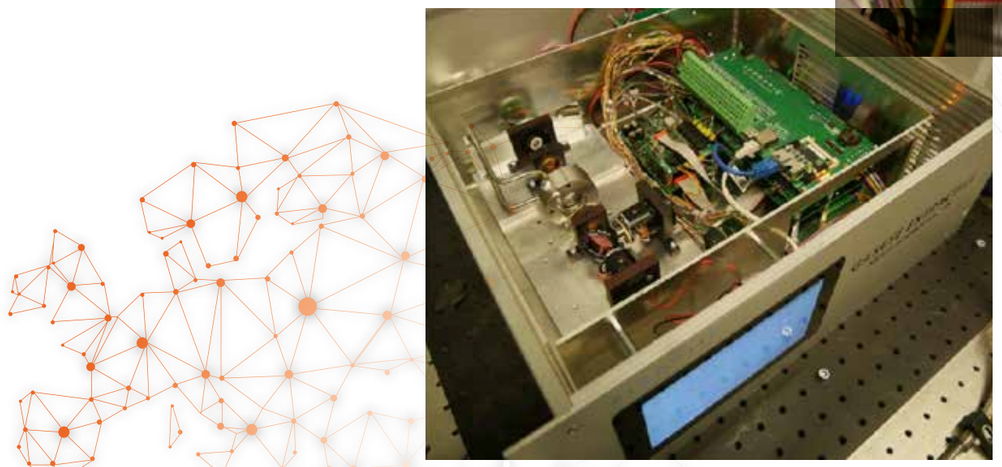
Contract Number
636930

CEA-Leti in iCspec

CEA-Leti has designed and built integrated beam combiners for three different wavelength domains based on the specifications agreed between the project partners.

One beam combiner is dedicated to a monitoring system working at nine specific wavelengths around 3.4 µm, one is dedicated to a continuous spectral domain around 6.8 µm and the more prospective third is dedicated to a large spectral domain around 9 µm.

CEA-Leti has also built, tested and delivered an ASIC capable of driving the QCL array and is now producing a modified version of this ASIC for the ICL array.



AirOptic multigas monitoring system installed at PREEM oil refinery facility for characterization, calibration and performance study. This system is now commercially available at AirOptic.
© CEA-Leti

IMPACT

AirOptic now commercializes a monitoring system based on the iCspec results.

Objectives

Real-time measurements of multi-components in process streams respond to long demanded industry requirements for fast, accurate, reliable and cheap process analyzers. Growth of these currently unavailable systems will lead to a paradigm change throughout the process control and production chain. The iCspec project is focusing on developing compact, robust, maintenance-free sensors for fast, in-line, multi-species measurement of chemical composition for process analytics involving multiple technically relevant gases including hydrocarbons. The projected sensors will replace expensive, polluting, state-of-the-art systems. Established laser-based, in-line gas sensing is being extended to the mid-infrared "chemical fingerprint" spectral range for multi-species detection.

Project developments are based on two key operations: (1) Integration of mid-IR laser arrays and, (2) Advancement of spectroscopic and chemometric data evaluation. Demonstrators are integrated into the control loop at a petro-chemical plant allowing significant improvements including optimized product quality, minimized waste, reduced environmental pollution and greater safety in cases, in which hazardous conditions need to be immediately detected.



Publications

• «Integrated TDLS-Gassensors - from NIR to MIR», A. Popescu, 6th Gassensor-Workshop, 9 Sept. 2015, Freiburg, Germany.

• «Trace gas sensing - challenges and opportunities of an emerging application area for novel semiconductor lasers", A. Forchel, 21st International Conference on Electronic Properties of Two-Dimensional Systems (EP2DS-21), 26-31 July 2015, Sendai, Japan.

• «Mid-Infrared (~2.8 um to ~7.1 um) Interband Cascade Lasers", S. Höfling, R. Weih, M. Dallner, J. Scheuermann, L. Naehle, M. Fischer, J. Koeth, M. Kamp, SPIE Optics + Photonics, 9 – 13 Auguts 2015, San Diego, USA.

• «Multiplexing photonic devices integrated on a silicon/germanium platform for the mid-infrared", P. Labeye, A. Koshkinbayeva, P. Barritault, O. Lartigue, M. Fournier, J.-M. Fedeli, S. Garcia., S. Nicoletti, L. Duraffourg, SPIE Photonics West, 28 Jan. - 2 Feb. 2017, San Francisco, USA.

Pierre Labeye
pierre.labeye@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



InDeal

Objectives

Faced by climate change and coupled with the need to secure sustainable economic growth and social cohesion, Europe must achieve a genuine energy revolution to reverse present-day unsustainable trends and live up to ambitious policy expectations. A rational, consistent, far-sighted approach to heating and cooling is key to ensuring this transformation. In this connection, district heating and cooling systems need to be more efficient, intelligent and cheaper. The InDeal project offers an innovative platform that creates a fair distribution of heating and cooling among the buildings within the network by, (i) real–time energy consumption data gathering via artificial intelligent meters, (ii) identifying and evaluating network building needs and demands for heating and cooling depending to energy efficiency, energy consumption and type of building (EDP tool), (iii) predicting short-term and long-term weather conditions, and forthcoming heating and cooling demands (EDP tool), (iv) monitoring and controlling the amount of energy stored in the network storage stations and substations (SMT), (v) ensuring 24/7 monitoring of the DHC system through a central control platform and (vi) minimizing heat losses via novel pipe design solutions and innovative insulation materials. InDeal's goal is to transform today's DHCS into a new next-level automated DHCS that will guarantee the system's higher overall energy efficiency by ensuring fair distribution of heating and cooling energy demands. In achieving this, InDeal represents a significant step forward to wider use of intelligent district heating and cooling systems and integration of renewables, waste and storage.

http://www.indeal-project.eu/

Keywords
Energy harvesting
Internet of Things (IoT)
Smart building
Thermal energy harvester
Water distribution
Water flow harvester

InDeal at a glance

33 months
Jun. 2016 > Feb. 2019

EC Programme
H2020-EE-13-2015
Technology for district heating and cooling

Project Coordinator
City University (GB)

Partners
CY: Center for Technology Research & Innovation (CETRI)
ES: Naitec
FI: Net Technologies
FR: CEA-Leti, SERM, SNCU
GB: City University
GR: Centre for Research & Technology Hellas (CERTH)
PL: Iznab, Promar
SI: Energetika

Total budget
€ 2.0 m.

EC Contribution
€ 2.0 m.

Contract Number
696174

Innovative Technology for District Heating and Cooling

InDeal is an innovative project that focuses on developing energy-efficient, eco-friendly and cost effective solutions for District Heating and Cooling Systems (DHCS). The project aim is to lower energy demand for DHC and improve system efficiency by developing better system monitoring tools, which can curtail energy losses and reduce customer costs.

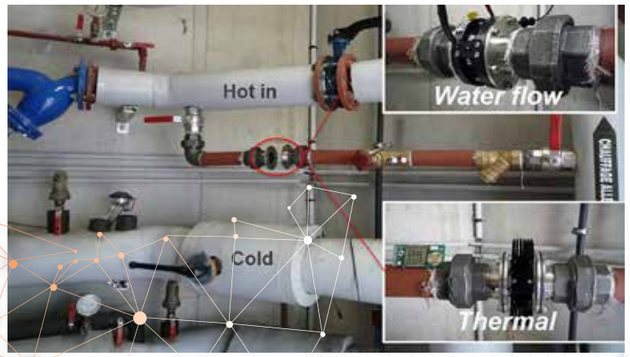
CEA-Leti in InDeal

CEA-Leti's main contribution to InDeal is development of **energy harvesting solutions**, specifically a water flow energy harvester and a thermal energy harvester. The aims are, (i) **to supply in-line intelligent water meters** able to work autonomously for years by replacing batteries and, (ii) **to improve quality** and **reduce costs** of water network monitoring (flow rate, temperature, pressure, leakage, pH, etc.).

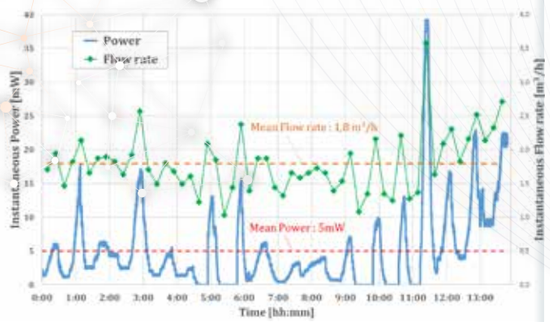
Micro-turbine (cm²)-based water flow and thermal energy harvesters have been designed, modelled and fabricated for a few m/s or L/min to ensure compatibility with building environments. Both systems have been tested in the laboratory and in a real environment.

Water flow energy harvester
- **First work** to optimize a centimeter-scale water flow harvester and ensure its long-term characterization in a real application case (Montpellier Odysseum heating and cooling district).
- **High output powers** at high flow rates (490mW@9m3.h-1) for cold and hot water with very low pipe pressure losses (<50 mbar). Mean power of 5mW (typical LED consumption).
- Proportionality between turbine rotational speed, instantaneous power and flow > the system can be used as an **autonomous flowmeter**.
- 4-month test in **heating system substation**.
- Presence of propeller fouling and dirtying did not degrade its operation.

Comparison with thermal energy harvester
- Peak at 34.8mW in the **real environment** due to high ΔT (water temperature 56 °C; substation temperature 17.5 °C), typical power for RF reception.
- Ease of installation (no requirement to stop flow since harvesters can be installed around pipes).
- **High output power** at high temperature gradient.
- No fouling.
- Not suitable for cold water pipes.



Tests in real environment: integration of water flow microturbine and thermal energy harvester in SERM substation in Montpellier, France.
© CEA-Leti



Instantaneous power and flow rate as a function of time during overnight test. Following demand flow rates between 1 and 4 $m^3.h^{-1}$ and T° ~ 50°C with few interruptions due to a too low flow rate (<1,5 $m^3.h^{-1}$).
© CEA-Leti

IMPACT

This first work involved long-term characterization of an optimized water flow harvester in a heating and cooling water network to provide new opportunities for future industrial transfer of the autonomous flowmeter. Impact in the scientific community with a journal publication on the experimental study of axial flow water turbines in Smart Materials and Structures, and presentations at international conferences. New collaborations including close cooperation with NAICTEC (Spain) and SERM (France).

Publications

- *«Cm-Scale Axial Flow Water Turbines for Autonomous Flowmeters: an Experimental Study», P.Gasnier, E Saoutieff, O. Soriano, B. Alessandri, J. Ojer-Aranguren, S. Boisseau, Smart Materials and Structures, 27 115035 (12pp), 2018.*
- *«Performances of a cm-scale water flow energy harvester in real environment for autonomous flowmeters», E. Saoutieff, P.Gasnier, S.Boisseau, J.Oyer-Aranguren, I.Rodot, Proc. PowerMEMS, Daytona Beach, USA, 2018.*
- *«Energy Harvesting for Autonomous Sensors», E. Saoutieff, P.Gasnier, S.Boisseau, EnerGaia, Montpellier, 2018.*
- *«Innovative technologies for district heating and cooling: InDeal project», S. Moustakidis, I. Meintanis, N. Karcanias, G. Halikias, E. Saoutieff, P. Gasnier, J. Ojer-Aranguren, A. Anagnostis, B. Marciniak, I.Rodot, E. Lezak, J. Pluta, M. Penev, H. Jäppinen, S. Petit, M. Krajnc, A. Eleftheriou, K. Kouvaris, Computer Science & Mathematics, Proceedings 2019, 5, 1, MDPI, February 2019.*

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Elise Saoutieff
elise.saoutieff@cea.fr

Bernard Strée
bernard.stree@cea.fr


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MIRPHAB

MIRPHAB
CHEMICAL SENSING AND SPECTROSCOPY

www.mirphab.eu

Keywords
Chemical sensing
Micro photoacoustic cell (µPA cell)
Mid InfraRed PHotonics devices
Quantum Cascade Lasers (QCLs)
Spectroscopic

MIRPHAB at a glance

60 months
Jan. 2016 - Dec. 2020

EC Programme
H2020 ICT-28-2015 - Cross-cutting ICT KETs

Project Coordinator
CEA-Leti (FR)

Partners
AT: Quantared
BE: IMEC
CH: Alpes Laser, CSEM
DE: Bosch, Fraunhofer Gesellschaft, NanoPlus
FR: III-V Lab, CMP, EPIC, mirSense, Tematys
GB: Cascade Tech., CSTG, IQE
IT: Electrolux
NL: Phoenix BV
NO: NEO Monitors
PL: Vigo

Total budget
€ 17.2 m.

EC Contribution
€ 17.2 m.

Contract Number
688265

Mid InfraRed PHotonics devices fABrication for chemical sensing and spectroscopic applications

MIRPHAB is a pilot line offering open access to industrials for prototyping and manufacturing Mid-IR devices detecting chemicals in gases and liquids. The goal of MIRPHAB is to foster emergence of new market segments for optical sensing by reducing investment cost to access innovative MIR solutions.

Objectives

The main objectives of MIRPHAB are to:
• Provide a reliable supply chain of mid-infrared (MIR) photonic components for companies including, in particular, SMEs already active in analytical MIR sensing
• Facilitate access to innovative MIR solutions for companies (including SMEs) working in the field of analytical sensors by reducing investment costs through providing open access to already developed design and testing technologies
• Attract companies new to the field of analytical sensors, which are aiming to integrate µ-sensors into their products.

Key technology breakthrough and challenge:
• Miniaturization at chip/package level as key leverage tool for adding functionalities, improving performance and enforcing standardization, while curtailing costs
• Mixing and matching different technologies on the same platform.

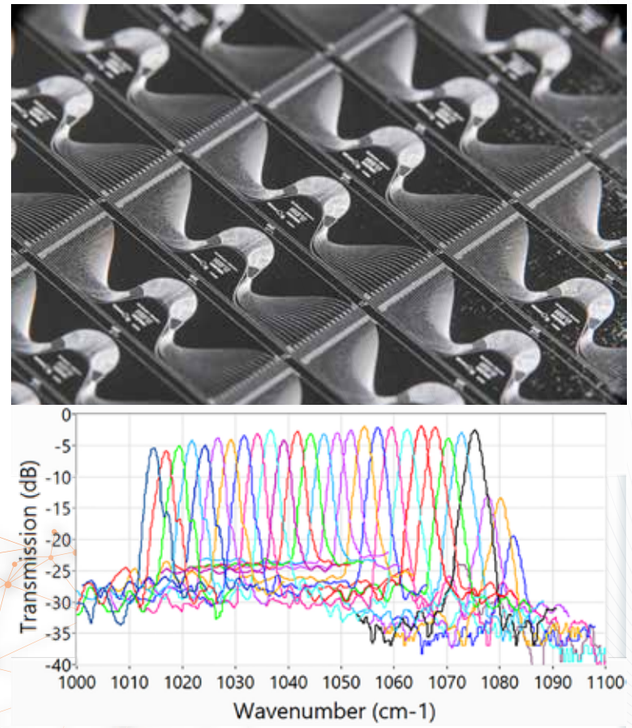
Market potential:
• Deploying new products swiftly on the market, fast-tracking key technological breakthroughs to high-added-value products
• Paving the way to large scale industrialization of Mid-IR spectroscopic sensing.

CEA-Leti in MIRPHAB

Technical achievements
In relation to QC laser assembly, different Mid-IR multiplexer technologies have been developed for the broad wavelength spectral range between 4.5 and 12 µm. To extend the spectral range beyond 8 µm in the LWIR region, the platform has been matured to feature a Ge core surrounded by thick SiGe layers. Input and output facets for QCL butt coupling have been deeply co-etched onto the wafers. Chip separation has been ensured by partially dicing the back side of the wafers. Good multiplexer performance characteristics were achieved and this technology allows operation at wavelengths, at which gases such as NH3, acetone, ozone or benzene can be detected.

Microphones have been designed and fabricated using the “M&NEMS” technological process based on manufacturing, from an SOI wafer, a thin NEMS part for the gauges and a thick MEMS part for the diaphragm. Two microphones have been mounted on top of a mini-photoacoustic cell and a measurement setup has been developed to read out the microphone output signal generated by the piezoresistive detection scheme. Experimental tests with CO2 gas have provided good performance characteristics equivalent to commercial microphones.

Organizational and Commercial Achievements
The MIRPHAB project mission is to reduce commercial risk by offering technical and financial support for developing chemical sensors. The MIRPHAB pilot line is an all-service integrated pilot line for designing MIR chemical sensors in Europe. A sustainable organization capable of supplying Mid-IR chemical sensor prototyping and manufacturing services has been set up. European and non-European companies can now fabricate their own optical sensors via MIRPHAB.



Arrayed WaveGuide (AWG) combiner working in the Mid-IR (9 to 10 µm) range: detail of in the devices fabricated on a Si wafer (top) and (bottom) experimental measurement of the transfer characteristic for a 33 inputs device.
© CEA-Leti

IMPACT

MIRPHAB is the first initiative offering prototyping of miniaturized optical sensing systems based on user specifications. It addresses a market segment, which has been constantly expanding in recent years, and is attracting industrial groups unfamiliar with these technologies. MIRPHAB is a sustainable source of all MIR sensor components, facilitating their market introduction and thereby reinforcing European industry’s competitiveness in this sector. The goal is to promote “a single face to the customer” via open access to the entire detection chain for MIR analytical sensors.

Publications

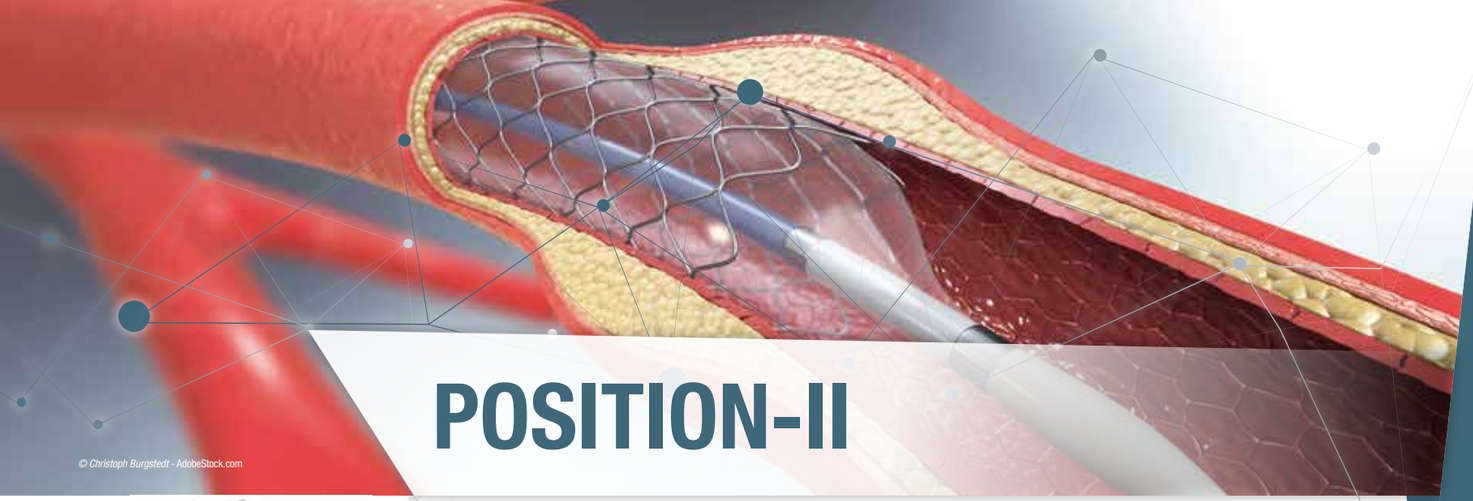
• «EU pilot lines for integrated photonics», J.-M. Fedeli, S. Nicoletti, L. Lagae, I. Artundo, P. O'Brien, 2017 IEEE 14th International Conference on Group IV Photonics (GFP), 79-80,2017, IEEE.
• «Mid-Infrared Chemical Sensors for Transport», A. González, J. Pozo, S. Nicoletti, Environment and Space: It's time for miniaturized sensing to reach the markets, Optik & Photonik,12,5,18-19,2017.
• «Mid-infrared (Mid-IR) silicon-based photonics», J.-M.Fedeli, S. Nicoletti, Proceedings of the IEEE, 99, 1-11, 2018, IEEE.
• «Quantum Cascade Laser Integration on Silicon for Gas Sensing», M. Carras, M. Brun, J.-M. Fedeli, J.-G. Coutard, L. Duraffourg, G. Maisons, G. Aoust, S. Nicoletti, J. Abautret, 2018 IEEE Photonics Society Summer Topical Meeting Series (SUM), 233-234, 2018, IEEE.
• «Miniaturization Challenges in Mid-IR Chemical Sensing: The MIRPHAB Pilot Line Approach», S. Nicoletti, 2018 IEEE Photonics Society Summer Topical Meeting Series (SUM), 231-232, 2018, IEEE.
• «Miniaturization of mid-IR sensors on Si: challenges and perspectives», S. Nicoletti, J.-M. Fedeli, M. Fournier, P. Labeye, P. Barritault, A. Marchant, A. Glière, A. Teulle, J.-G. Coutard, L. Duraffourg, Silicon Photonics XIV, 10923, 109230H, 2019, International Society for Optics and Photonics.
• «Photoacoustic cell on silicon for mid-infrared QCL-based spectroscopic analysis», J.-G.Coutard, A. Glière, J.-M. Fedeli, O. Lartigue, J. Skubich, G. Aoust, A.Teulle, T. Strahl, S. Nicoletti, M. Carras, MOEMS and Miniaturized Systems XVIII, 10931, 109310V, 2019, International Society for Optics and Photonics.

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Sergio Nicoletti
sergio.nicoletti@cea.fr

Jean-Marc Fedeli
jean-marc.fedeli@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



POSITION-II

www.position-2.eu

Keywords

Catheters, Micromachined Ultrasound Transducer, Microsystems

POSITION-II at a glance

36 months

Jun. 2018 > May 2021

EC Programme

ECSEL Joint Undertaking (Electronic Components and Systems for European Leadership)

Project Coordinator

Philips Research (NL)

Partners

BE : IMEC

CH: Comelec, Dyconex AG

DE : 3D-Micromac, Catena Germany GmbH, Cortec, Finetech GmbH & CO. KG, Fraunhofer IPMS, Fraunhofer IZM, Fraunhofer Research Institution for Microsystems and Solid State Technologies, Institut für Mikroelektronik Stuttgart, Johnson Matthey Piezo Products GmbH, Multichannel systems GmbH, Osypka

ES: Brio apps Alphasip, CIBER Centro de Investigacion Biomédica en Red, CIKAUTXO S.COOP, Fundacion Centro de Cirugia de Minima Invasion Jesus Uson, University Complutense Madrid, University of Zaragoza

FI: Aalto - Korkeakoulusaatio, Okmetic Oy, Picosun, Teknologian Tutkimuskeskus VTT, Tikitin

FR: CEA-Leti, Murata Integrated Passive Solutions, Philips Research Paris, Vermon

HU: MAT-EK, MTATK

IE: Analog Devices International (ADI), Brivant Limited T/A Lake Region Medical, Creganna medical, Tyndall National Institute

IT: Kessler Foundation for Research, Università degli Studi Roma Tre

NL: Catena Holding B.V., Delft University of Technology, Eindhoven University of Technology, Philips Electronics Netherlands B.V., Philips Medical Systems B.V., Reden B.V., Salvia Bioelectronics B.V.

PT: INESC-ID, Instituto de Telecomunicações

SE: SILEX

Total budget

€ 53.6 m.

EC Contribution

€ 13.4 m.

Contract Number

grant agreement Ecsel-783132-Position-II-2017-IA

Paving the way towards smart catheters

A pilot line for the manufacturing the next generation of smart catheters and implants is being developed in the POSITION-II project. This paves the way towards standard and intuitive systems for improving diagnosis through advances in open platform technologies.

Objectives

Around 10% of the West's population will be taken at a moment in life to a catheterization (cath) laboratory for angioplasty surgery (stent placement), treatment of arrhythmia or heart valve replacement. Fortunately, most of these procedures are minimally invasive and are assisted by a host of smart imaging and sensing catheters, which are the surgeon's "eyes and ears" at the point of operation.

Essential and life-saving as these smart instruments are, they are invariably manufactured using outdated and obsolete technology. Surprisingly, there has been little to no innovation over the last decade, although clinicians are calling for more functional instruments that are smaller, cheaper and easier to use. This lack of innovation is primarily due do instruments being manufactured using technological point solutions, which do not generate alone enough production volume to justify continuous innovation.

The ambition of the POSITION-II project is to achieve a breakthrough in this predicament by introducing open technology platforms for miniaturization, in-tip AD conversion, wireless communication, MEMS transducer technology and encapsulation. These platforms will be open to multiple users and for multiple applications. Open platform availability will allow manufacturers to raise smart catheter performance at lower cost and enable development of noval minimally invasive smart instruments. The platform approach will generate the production volume needed for roadmap-guided sustainable innovation.

CEA-Leti in POSITION-II

Almost all ultrasound transducers are today based on bulk poly- or single-crystalline piezo materials. These materials are difficult to work with and require mechanical dicing into individual transducer elements. This makes it cumbersome and expensive to manufacture 2D arrays for 3D imaging, miniaturize transducers for the use in catheters or produce high frequency arrays.

In recent years, CEA-Leti has developed know-how in the design and manufacture of microsystems such as micromachined ultrasound transducers (MUT) actuated by capacitive or piezoelectric means. Compared to standard piezo transducers, these MEMS transducers allow low-cost manufacturing of 2D arrays for 3D imaging for further miniaturization because a difficult and costly assembly step is eliminated; they thereby offer an overall lower transducer cost.

In the POSITION-II project, CEA-Leti is taking part in a comparative study of different MUT technologies. Actuation technology, material stack, actuation mode (conventional or collapse mode) and process flows are compared on an experimental basis. The goal of this benchmark is to evaluate the pros and cons of each technology and to assess its relevance for different applications, such as cardiovascular imaging, obstetrics, Doppler imaging or theranostics, to produce a common roadmap mapping application.

CEA-Leti brings its major manufacturing expertise by making its own transducers on its 8" MEMS platform. CEA-Leti also contributes to each step, from transducer specification to data analysis, to map the application space with the different technologies supplied by the other project partners.

The project outcomes are expected to support the industrial road-map for MUT, a key technology for the next generation of catheter and smart implants.



CEA-Leti's cleanroom.
© CEA-Leti / P. Jayet

IMPACT

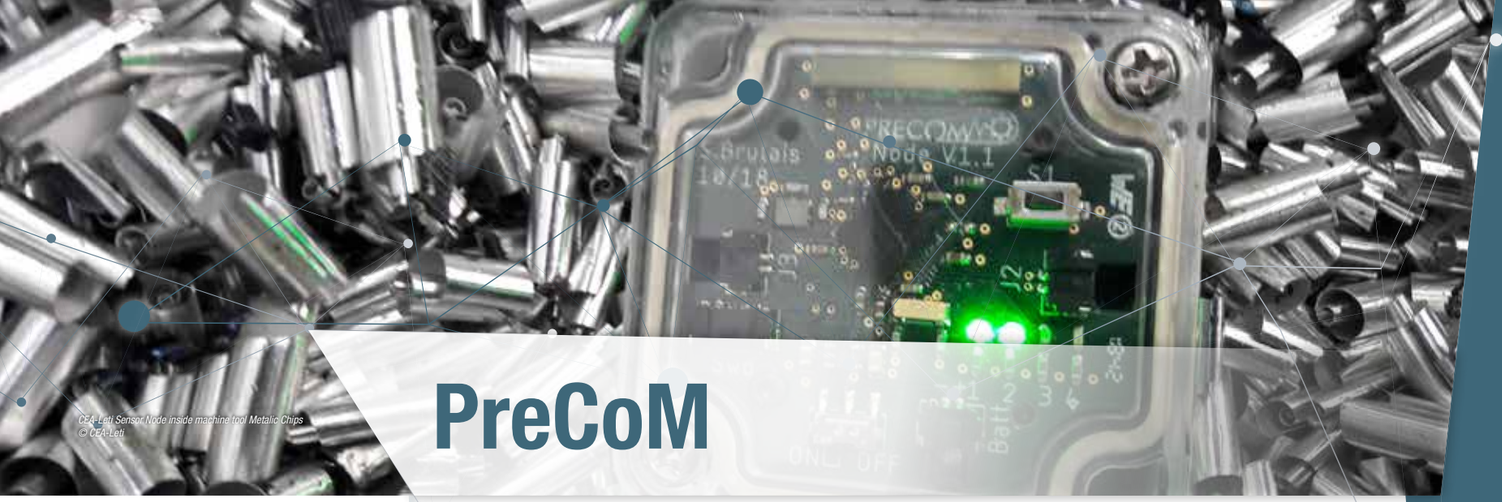
POSITION-II will enhance Europe's competitiveness in the field of minimal invasive surgery. It will prompt further development of European R&D and manufacturing capability in an innovative industrial segment of high economic importance, encompassing the micro-fabricated device itself and the various value chains. By bringing smart catheters into the domain of high volume manufacturing, POSITION-II will improve the quality of healthcare at a manageable cost.

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Bruno Fain
bruno.fain@cea.fr

Yves Quéré
yves.quere@cea.fr



CEA-Leti Sensor Node inside machine tool Metalic Chips
© CEA-Leti

PreCoM

Predictive Cognitive Maintenance Decision Support System

The aim of the PreCoM project is to create an innovative support system for production equipment maintenance. The main function of this system is to identify the outset of critical part (gear, bearing) deterioration and to determine its remaining life. The objective is to avoid intervention, limit repair operations and thus increase production efficiency.

https://www.precom-project.eu/

Keywords
Artificial intelligence
Embedded sensors
Modal tracking
Predictive maintenance
Self-healing

PreCoM at a glance

36 months
Nov. 2018 > Oct. 2020

EC Programme
H2020-FoF-09-2017
Industry 2020 in the Circular Economy

Project Coordinator
Linnaeus University (SE)

Partners
DE: Bosch Rexroth, Overbeck, Technical University of Chemnitz, Technical University of Munich
EL: Paragon
ES: Goma-Camps, Ideko, Itmati, Lantier, Sakana, Savvy, Soraluce
FR: CEA-Leti, Vertech Group
SE: E-Maintenance, Lineaus University
SK: Spinea

Total budget
€ 7.3 m.

EC Contribution
€ 6.1 m.

Contract Number
Grant agreement No 768575

CEA-Leti in PreCoM

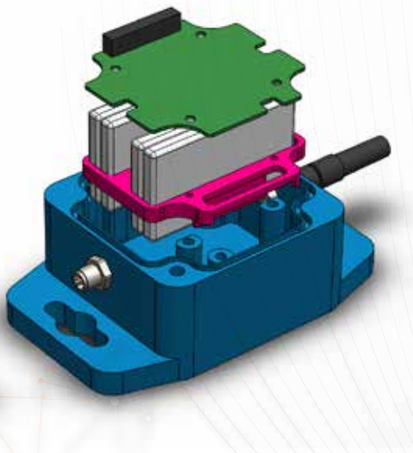
CEA-Leti's major role in the PreCoM project is to specify and develop a wireless multisensor platform. This platform will provide additional data (measurements) on machine tool equipment and assets, which will then be combined with production and maintenance data to enable a PreCoM disruptive maintenance approach to damage localization and prediction.

The main challenge for CEA-Leti is to develop long-lasting wireless sensor nodes to collect data as close as possible to critical moving parts in a harsh industrial environment.

Machine-tools are associated with harsh environments integrating moving parts, metallic structures and liquid cooling that can cause masking during Radio Frequency communication as well as strong vibrations. During the first year of the PreCoM Project, CEA-Leti has set up a preliminary communication node based on a Bluetooth Low Energy (BLE) toolkit. This preliminary node has been designed to overcome the technological limitations on wireless communication in a machine-tool environment. This node is associated with a wireless gateway, based on an embedded Linux microcomputer, for collecting the data through BLE. The wireless communication building block of the sensor node has been validated under real machining conditions (liquid coolant, hot chips, dynamic cutting, etc.) in collaboration with IDEKO provided by the Danobat Group, a PreCoM project partner.

Objectives

Cheaper, more powerful sensors and big data analytics offer an unprecedented opportunity for monitoring machine-tool performance and health. However, manufacturers only spend 15% of their total maintenance costs on predictive (unlike reactive or preventive) maintenance.
The aim of the PreCoM project is to deploy and test a predictive cognitive maintenance decision-support system capable of identifying and localizing damage, assessing damage severity, predicting damage evolution, assessing remaining asset life, reducing the probability of false alarms, providing more accurate failure detection, issuing orders to conduct preventive maintenance actions and ultimately increasing machine in-service efficiency by 10% or more.
The platform features four modules: a data acquisition module leveraging external sensors and sensors directly embedded in machine-tool components; an artificial intelligence module combining physical models, statistical models and machine-learning algorithms capable of monitoring individual health and supporting multiple assets and dynamic operating conditions; a secure integration module connecting the platform to production planning and maintenance systems via a private cloud and providing additional safety, self-healing and self-learning capabilities and a human interface module including production dashboards and augmented reality interfaces for facilitating maintenance tasks.
The project consortium includes three end-user factories, three machine-tool suppliers, one leading component supplier, four innovative SMEs, three research organizations and three academic institutions. Together, the team intends to validate the platform across a broad spectrum of real-life industrial scenarios (low volume, high volume and continuous manufacturing) and demonstrate the platform's direct impact on maintainability, availability, work safety and costs to document results in detailed business cases for widespread industry-wide dissemination and usage.



PreCoM node CAO.
© CEA-Leti

IMPACT

Business impact. Predictive maintenance solutions are a key driver of the Industry 4.0 revolution. Manufacturers are seeing maintenance as a strategic business function as they seek to reduce maintenance costs and downtime, and increase asset lifecycles. The primary objective of the PreCoM solution is to increase in-service machine-tool efficiency.
Knowledge impact. By merging knowledge from different areas of expertise (sensors, statistics, maintenance, production planning, artificial intelligence, augmented reality), the PreCoM project aims to create new global knowledge of Predictive and Cognitive Maintenance.

Publications

Workshop on Factories of the Future for the Automotive Sector:
B. Stree, «Predictive cognitive maintenance decision support system», Factories of the Future for the Automotive Sector, Brussels, 28 February 2018.

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Tristan Caroff
tristan.caroff@cea.fr

Bernard Strée
bernard.stree@cea.fr



PYCSEL

Objectives

The PYCSEL project development combines a printed pyroelectric organic sensor with active matrix TFT arrays on a mechanically-robust plastic foil. It focuses on user requirements in terms of easy system integration, conformability, ergonomics, large area acquisition and high resolution (Fingerprint Acquisition Profile plain 4-fingers - FAP60: 1600x1500 pixels @500 ppi).

The system involves integrating a printed pyroelectric Poly[vinylidene difluoride] (PVDF)-based sensor layer on a flexible Indium Gallium Zinc Oxide (IGZO) active matrix TFT foil to give a thin conformable fingerprint sensor without the need for any optical bulky and/or costly additional components. It offers differentiating properties for the portable governmental market since it provides a breakthrough in terms of mechanical robustness and conformability: advantages which also increase fingerprint sensor penetration into automotive (personalized human-machine interfaces or HMIs), machine-tool (user-restricted HMI), building (access control) and consumer (PCs) markets.



https://www.pycsel-project.eu/

Keywords
Fingerprint
Sensor
Thin and Organic Large Area Electronics (TOLAE)

PYCSEL at a glance

36 months
Jan. 2017 > Dec. 2019

EC Programme
H2020-ICT-02-2016
Research and Innovation Action

Project Coordinator
CEA-Liten (FR)

Partners
BE: Imec
FR: CEA, Idemia, IrLynx
IT: Bioage
NL: TNO
SE: Autoliv
SP: UC3M

Total budget
€ 3.8 m.

EC Contribution
€ 3.8 m.

Contract Number
732423

PYroelectric Conformable SEnsor matrix for Large area applications in security and safety

The PYCSEL project aims to develop and demonstrate highly innovative fingerprint sensors based on TOLAE technology. This involves combining an innovative active thermal sensing frontplane, using PVDF-based pyroelectric material, with an IGZO TFT backplane on a plastic flexible foil. This system offers high resolution and a large surface area compliant with FBI standards as well as multiple fingerprint capture for easy integration, ergonomic use in future innovative cost-efficient fingerprint identification and conformability-based grip recognition systems targeting governmental and automotive applications.

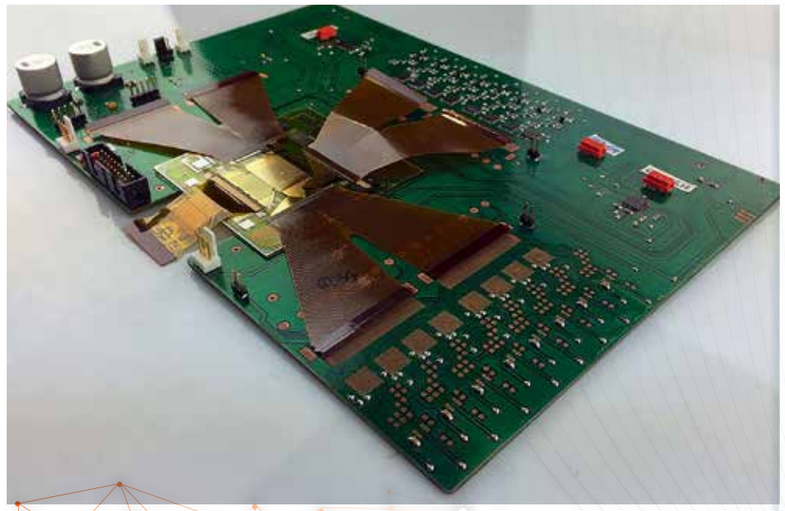
CEA-Leti in PYCSEL

The outcomes provided by the two CEA institutes involved in the project (CEA-Liten as coordinator and CEA-Leti as contributor).

Specifications, design and manufacturability
CEA has contributed to the mask layout of the three prototypes: PYCSEL1 is a basic test vehicle for process development, PYCSEL2 is an intermediate prototype capable of single finger acquisition and PYCSEL3 is the final 4-finger sensor. CEA has been the main contributor of thermal active sensing and has performed all the thermal simulations with COMSOL to predict the charges generated and the expected contrast between ridges and valleys, depending on layer organization and thicknesses, and injected thermal power.

Sensor process flow and reliability
CEA manufactures the frontplane section of the sensor located above the backplane IGZO-based TFT array made by TNO using printing-based technologies. The specific pyroelectric layer is composed of PVDF-TrFE. CEA has also checked the frontplane reliability: the sensor must resist environmental changes and chemical and mechanical constraints as the fingers are contacting.

System integration
CEA is participating in the system architecture design using inputs from thermal simulations conducted in WP1. It is also characterizing the results for comparison with simulations.



PYCSEL 2.
© CEA-Leti

IMPACT

This is the first very large (4-finger) thermal active fingerprint sensor on a IGZO-based TFT active matrix using PVDF as the pyroelectric layer.

Publications

- *«PYCSEL – Project introduction / EAB Research Projects Conference», J.F. Mainguet, (EAB-RPC) 2017 / Darmstadt / 19-sep-2017.*
- *«Best Publicly-Funded Project Demonstrator Award: PYCSEL H2020 - Thin Thermal Fingerprint Sensor», A. Martinent, LOPEC 2019 / Munchen / 20-mar-2019.*
- *«Un capteur d'empreinte digitale thermique actif et la détection du vivant», J.F. Mainguet / PYCSEL, Journées Nationales 2019 du GDR Sécurité Informatique / Paris / 13-jun-2019.*
- *«A new flexible active thermal fingerprint sensor: hot image results», J.F. Mainguet, M.Pouet / PYCSEL, EAB Research Projects Conference (EAB-RPC) 2019 / Darmstadt 17-sep-2019.*
- *«A large-area curved pyroelectric fingerprint sensor», JF. Mainguet, D. Gallaire, A. Martinent, A. Revaux, M. Benwadih, S. Charlot, A.J.J.M van Breemen, J.-L. van der Steen, H.B. Akkerman, A.J. Kronemeijer, G.H. Gelinck, M. Pouet, J.-Y. Fourré, S. Sinopoli, U. Emanuele, L. Fritsch, J. Liu Jimenez, J. Karlsson, F. De Roose, S. Steudel / IEDM 2019 65th International Electron Devices Meeting / San Francisco / 10-dec-2019.*

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Audrey Martinent
audrey.martinent@cea.fr

Jean-François Mainguet
jean-francois.mainguet@cea.fr

Bernard Strée
bernard.stree@cea.fr



REDFINCH

mid infraRED Fully Integrated CHemical sensors

The REDFINCH project involves building three fully-integrated, PIC-based, chemical sensor demonstrators for:
- **Process gas analysis at refineries**
- **Gas leak detection at petrochemical plants**
- **Liquid sensing for protein analysis in the dairy industry.**

www.redfinch.eu

Keywords
Photoacoustic
Photonic Integrated Circuit (PIC)
Quantum Cascade Lasers (QCL)

REDFINCH at a glance

42 months
Dec. 2017 > Jun.2021

EC Programme
Horizon 2020

Project Coordinator
CEA-Leti (FR)

Partners
AT: TU Wien
CZ: Argotech
DE: Endress Hauser, Fraunhofer IPM
FR: mirSense, Université de Montpellier
IE: CIT

Total budget
€ 3.9 m.

EC Contribution
€ 3.9 m.

Contract Number
78024

CEA-Leti in REDFINCH

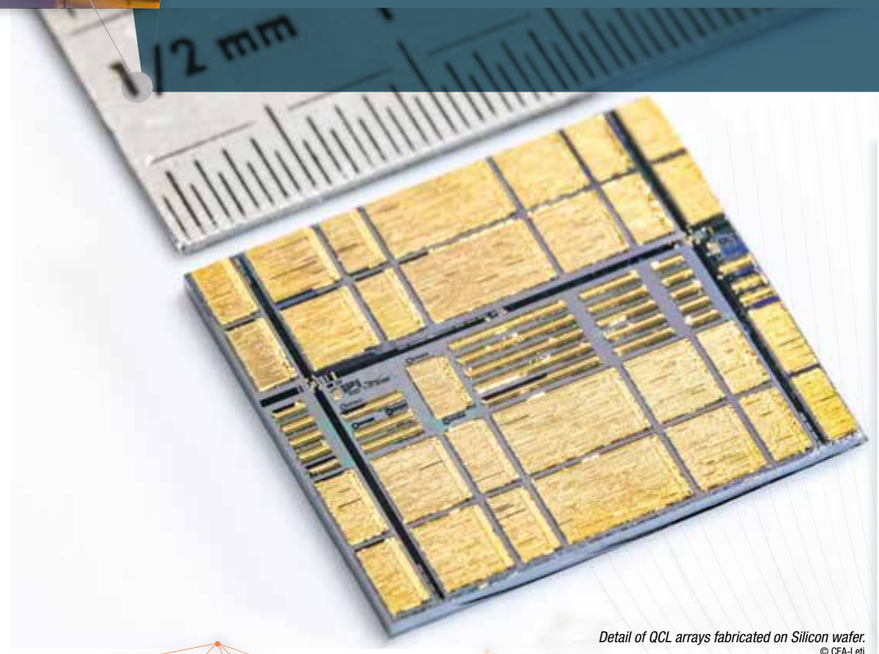
Photoacoustic (PA) spectroscopy is among the most sensitive methods used to monitor chemical emission or detect gas traces. In the mid-infrared, where most gases of interest have their strongest absorption lines, this technique takes advantage of the high optical power and room temperature operation of Quantum Cascade Lasers (QCLs). We have recently demonstrated that centimeter-size PA cells can compete with bulky commercial systems for gas sensing without any compromises on performances. This year, CEA-Leti has taken a new step towards cost reduction, extreme integration and mass deployment of such PA sensors with a miniaturized silicon PA-cell fabricated on standard CMOS tools.

This new sub-centimeter PA cell built on a silicon platform has been designed, fabricated and characterized. Initially, the component was designed using a detailed physical model accounting for viscous and thermal losses and metamodel-based optimization techniques. It has been subsequently fabricated on CEA-Leti's 200 mm CMOS pilot line. Several wafers have been released and diced. Single chips have been assembled with commercial capacitive microphones; these have been characterized on the CEA-Leti reference gas bench. The results of the photoacoustic simulations and acoustics experiments agree closely and the tiny PA cell exhibits a sensitivity down to ppm level for CO2 at 2300 cm-1 and for CH4 at 3057 cm-1, even in a gas flow.

Heterogeneous integration of QCL sources on silicon is starting to stabilize. The main objective is to reduce the cost of these sources to ensure wide availability of their intrinsic qualities. Basically, one can relate the cost of MIR lasers to the costs associated with 1) epitaxy, 2) manufacturing yield and 3) packaging. CEA-Leti has fabricated several wafers on its CMOS pilot line. Thousands of QCL sources have been characterized and have exhibited excellent fabrication yield and state-of-the-art performance.

Objectives

Mid-infrared photonic integrated circuits (mid-IR PICs) are the subject of increasing interest due to the large number of sensing applications in the 2-20 µm wavelength range. Most molecules exhibit absorption fingerprints in the mid-IR range corresponding to their rotational/vibrational energies. Tunable diode laser absorption spectroscopy thus allows detection and concentration measurements of many biological and chemical species. This is of crucial interest for many societal applications including health monitoring and diagnosis, detection of biological compounds, monitoring of toxic gases or of greenhouse gas emissions responsible for global warming. However, state-of-the-art sensing systems are large and delicate, which greatly hampers potential applications.
The REDFINCH project involves hybrid and monolithic integration of III-V diode and Interband Cascade/Quantum Cascade materials with silicon to create high-performance, cost effective sensors based on Photonic Integrated Circuits.
Integration creates extremely robust systems, in which discrete components are replaced by on-chip equivalents, prompting simultaneous improvement in ease of use and reduced cost. Silicon photonics leverages the advantages of high-performance CMOS technology, offering low cost mass manufacturing, high fidelity reproduction of designs and access to high refractive index contrasts enabling high-performance nanophotonics.



Detail of QCL arrays fabricated on Silicon wafer.
© CEA-Leti

IMPACT

The two outcomes of the REDFINCH project represent major steps towards dissemination of MIR technologies. Regarding photoacoustics, they have been obtained thanks to close cooperation with the Fraunhofer Institute's teams and may be exploited by mirS and EH. The REDFINCH website, conference communications and press releases have made it possible to establish preliminary contacts with industrials such as BP, BAE systems, Thorlabs and the US Naval Research Laboratory.

Publications
• «Photoacoustic cell on silicon for mid-infrared QCL-based spectroscopic analysis», J.-G. Coutard, A. Glière, J.-M. Fedeli, O. Lartigue, J. Skubich, G. Aoust, A. Teulle, T. Strahl, S. Nicoletti, M. Carras, L. Duraffourg, Best paper award photonic west 2019 : MOEMS and miniaturized system XVIII.

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Jean-Guillaume Coutard
jean-guillaume.coutard@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



SAFESTRIP

SAFE and Green Sensor Technologies for Self-explaining and Forgiving Road Interactive Applications

SAFESTRIP aims to integrate new sensor and communication technologies into low-cost, integrated strip markers on the road. This system will provide personalized in-vehicle messages for all road users at reduced maintenance cost. It incorporates full recyclability and real-time predictive road maintenance functions.

https://safestrip.eu/

Keywords
Adherence
Maintenance cost
Predictive infrastructure maintenance
Road embedded sensors
Road safety
Smart sensors

SAFESTRIP at a glance

36 months
May 2017 > Jun. 2020

EC Programme
H2020-MG-3.4-2016
Transport infrastructure innovation to increase the transport system safety at modal and intermodal level (including nodes and interchanges

Project Coordinator
Certh (GR)

Partners
BE: Ertico,
DE: Fraunhofer/IAO
FR: CEA-Leti, Valeo, Conti
GR: Certh, Upat, Attd, Computer Technology Institute & Press (CTI), Institute of Communication and Computer Systems (ICCS)
IT: University of Trento, Relab, Consiglio Nazionale delle Ricerche (CNR), Piaggi, Swarco, Centre Ricerche Fiat (CRF), A22
SP: Cidaut

Total budget
€ 4.6 m.

EC Contribution
€ 4.6 m.

Contract Number
723211

CEA-Leti in SAFESTRIP

CEA-Leti's contribution to the SAFESTRIP project has been specifying general project sensors and developing on-road sensors.

Sensor specifications have been drawn up to fulfil the need expressed in the use case scenarios defined by project end users. These specifications are for road sensors but also for all other sensors that cannot be installed on the road and need to be connected to the main infrastructure network platform.

The main contribution of CEA-Leti has been the specifications, development, testing and integration of the «On-Road Unit» (ORU), the central part of the «On-Road Platform», which allows acquisition of on-road sensor measurements.

The ORU has been designed to collect data from the project partners' sensors. It is connected to a nano-based gas sensor developed by CNR and a dynamic vehicle detection unit developed by CERTH.

The ORU has been designed to collect and transmit data from other sensors as well as humidity and temperature data based on a Bluetooth Low Energy transmission protocol implemented in a very low power, low profile system.

The combined on-road data allow this global SAFESTRIP system to improve road safety through car localization and speed and friction measurements for the global external conditions.

SAFESTRIP merges data from on-road sensors with data from all other system and displays it to end users via a dedicated vehicle on-board unit.

Objectives

Project Aim 1. Development of a novel micro/nano sensor system called SAFESTRIP, which is integrated into road pavement tapes/markers, to provide advanced safety functions to all road users at a fraction of the cost of existing I2V/V2I nodes and roadside equipment (VMS, VDS, etc.).
Project Aim 2. Support for predictive infrastructure maintenance through dynamic road embedded sensor input.
Project Aim 3. Provision of road infrastructure (mainly highways and interurban roads but also ring-roads and some rural roads) that is self-explanatory (personalized own language information and preferred system format for each driver/rider) and forgiving (key I2V/V2I information provided to vehicle cooperative system, e.g. dynamic speed limit, friction coefficient factor) for all vehicle types.
Project Aim 4. Extension of this concept to parking areas and key intermodal nodes, e.g. railway level crossings, port loading/uploading areas, logistics facilities and, above all, work areas.
Project Aim 5. Order-of-magnitude reduction of infrastructure operating (VMS/VSL information and toll collection functions), installation and maintenance costs, making infrastructure almost energy autonomous and its modules fully recyclable.
Project Aim 6. Provision of key information on road, weather and upcoming traffic conditions to C-ITS-equipped and autonomous vehicles to support dynamic trajectory calculation and optimization.
Project Aim 7. Support for a wide range of added value services (information "pushed" to driver/rider) and facilitating of SAFESTRIP rapid market deployment and sustainability through efficient business models.
Project Aim 8. System appraisal in a controlled environment (test beds in Spain and France and two closed test tracks in Italy) and in real life conditions at two locations (highways in Greece and Italy) using four cars and 3 PTW demonstrators. Performance validation, user interface evaluation and acceptance aspects, and finally, assessment of system impacts on safety, mobility, the environment and European industrial competitiveness.



Control center.
© A22

IMPACT

Project scientific impacts include:
- Micro and nano sensors in road applications
- Easy and cost effective dynamic information-based infrastructure monitoring
- Much more accurate hybrid estimation of road friction
- New V2X communication possibilities through deployment of latest 802.11p wireless network infrastructure hardware.

Project safety impacts include:
- Support for driver in most critical and dangerous conditions in a highway environment
- Enhanced on-board security functions through friction coefficient calculation.

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Antoine Robinet
antoine.robinet@cea.fr

Bernard Strée
bernard.stree@cea.fr



SARMENTI

Objectives

The SARMENTI project is developing and validating a cost effective, portable, low-power, multisensor system, connected to the Cloud, for conducting in-situ soil nutrient analysis and for decision-making support to farmers through real-time monitoring of soil fertility. In tandem with measurement of local environmental conditions, especially environmentally harmful gas production just above the ground, SARMENTI provides farmers with digitized data for performing suitable, timely fertilization operations; these will have a direct impact on crop growth and yields, the environment, soil and water quality, and fertilization cost reduction. In addition to soil nutrients in farming, other digitizing applications developed by SARMENTI include water quality monitoring of surface, ground and drinking water.

http://sarmenti-project.eu/

Keywords
Decision support
Edge computing
Gaseous emission
In situ
IoT node cyber-security
Real-time measurement
Selectivity
Soil nutrients at ppm concentration

SARMENTI at a glance

36 months
Jan. 2019 > Dec. 2021

EC Programme
H2020-ICT-07-2018: Electronic Smart Systems (ESS)

Project Coordinator
CEA-Leti (FR)

Partners
AT: CH: CSEM SA
FR: Terrasolis
IE: Teagasc, Tyndall - University College of Cork
IT: STMicroelectronics
RO: Atos, Spiro

Total budget
€ 3.9 m.

EC Contribution
€ 3.9 m.

Contract Number
825325

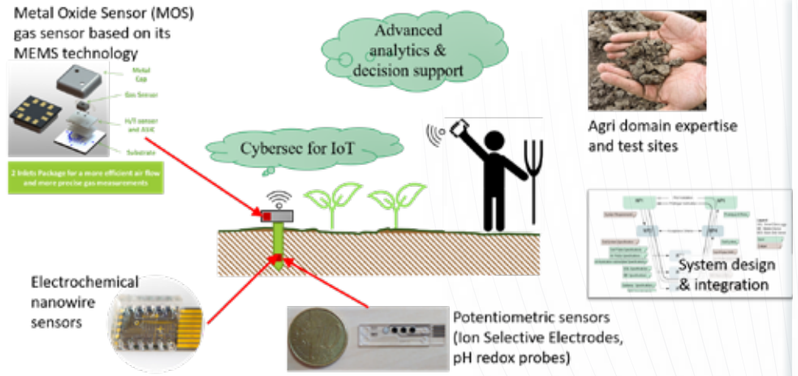
Smart multisensor embedded and secure system for soil nutrient and gaseous emission monitoring

The SARMENTI project makes soil nutrient analysis and gaseous emission monitoring available by developing a portable, Cloud-connected, low-power, multisensor system to provide decision-making support to farmers through real-time monitoring of soil quality.

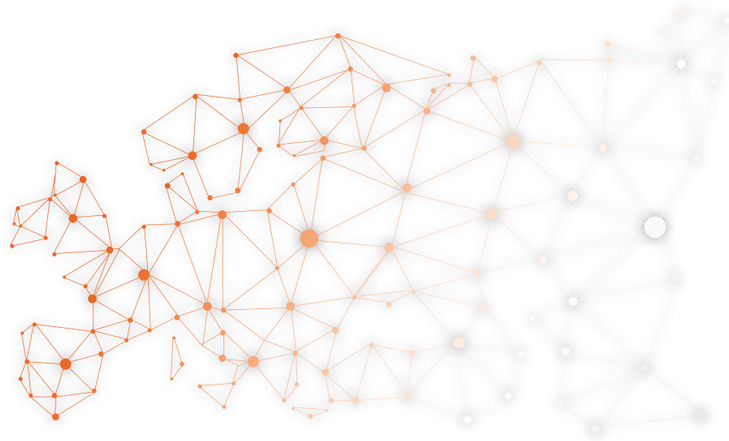
CEA-Leti in SARMENTI

CEA-Leti is project coordinator and is contributing to the following activities:

- System integration and functional testing, in which it is responsible for testing plans and tests on the whole system
- Optimization of electrochemical sensors for measuring nutrients (K, P, N) in the soil
- Development of a passive pump, which will extract water from the soil before measuring nutrient concentration
- End-to-end cyber-security.



CEA Cloud-connected Low-power Multi-sensing system in a real-time soil-quality management scenario.
© CEA-Leti



IMPACT

Such a system is a «must have» for assisting farmers in managing fertilization applications, especially with regard to European nitrate directives.

Publications

SARMENTI: Smart multisensor embedded and secure system for soil nutrient and gaseous emission monitoring, S. Lesecq, et al., Smart system Integration Conference, SSI, Barcelona, Spain, 2019.

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Suzanne Lesecq
suzanne.lesecq@cea.fr

Dider Belot
didier.belot@cea.fr



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SILENSE

Objectives

The SILENSE project is developing and improving smart acoustic technology blocks on different levels – hardware, software and system – to build multiple applications.

SILENSE is lowering the cost and energy consumption, while improving the performance (directivity, fractional bandwidth, dynamic range, frequency range, sensitivity and efficiency) of micro-acoustic transducers.

The project is developing package and assembly technology. More specifically, heterogeneously and monolithically integrated arrays of micro-acoustic transducers with their supporting electronics and is also providing dedicated low-power IC design.

It is developing smart algorithms for acoustic data communication and sensing based on combining voice/speech, digital sound modulation and gesture control using the same transducer(s).

https://silense.eu

Keywords
UltraSound

SILENSE at a glance

36 months
May 2017 > May 2020

EC Programme
H2020-ICT-01-2016

Project Coordinator
NXP

Partners
FR: CEA, IMEC, VERHAEART, SOMATES, SYNOPSIS, TUD, Coventor, IMT, INFINEON, TUVB; TUC, CTR, LINZ Universitat

Total budget
€ 29.6 m.

EC Contribution
€ 8.7 m.

Contract Number
737487-2

Ultra Sound Interfaces and Low Energy Integrated Sensors

The SILENSE project is researching acoustic technologies and is developing concepts to activate and control devices by gesture, data communication and indoor positioning based exclusively on these innovative technologies. These concepts can be used in different domains including wearables, automotive and smart home applications.

CEA-Leti in SILENSE

CEA-Leti is focusing on reducing the electronic power consumption in three ways:
1/ at the interface level through combined design of transducers and electronic interface using physical transducer models),
2/ at the analog-to-digital interface using event-driven conversion and beamforming and,
3/ processing of received information (CEA-Leti is designing the architecture of an adaptable ultra-low power processor based on advanced neuromorphic processing methods.



© SILENSE

IMPACT

Humans communicate mainly through speech and physical gestures. The technologies being developed in the SILENSE project take the way we communicate naturally one step further: from communication between humans to communication between humans and objects. This process will become increasingly important in an IoT-dominated world. Application of the project-developed technologies in multiple domains will offer many benefits to the general public, ranging from enhanced user experience to improved health and safety. Specific examples include:

• Intuitive user interfaces in mobile and wearable devices; these interfaces are currently one of the major mobile market differentiators. Audio sensing allows touchless activation and control of mobile devices. Moreover, dirty touch screens will become a thing of the past so user experience and hygiene will be enhanced

• Improved hygiene by touchless control: implementation of technologies enabling touchless control of objects can lead to improved hygiene conditions in buildings, hospitals and the home

• Enhanced safety by touchless control: sound/voice activation/control of systems in cars (e.g. navigation, entertainment and climate control) and control of machinery in industrial applications

• Enhanced security by gestural authentication: based on today's needs for stronger authentication processes, gestural identification represents a new factor in increasing the diversity and hence the robustness of authentication scenarios

• Enhanced quality of life for disabled persons or the elderly unable to move could also take advantage of audio and gesture recognition. Persons suffering from hearing/speech impairment could benefit from sign language interpretation.

Publications

• *"Guided Embodiment and Potential Applications of Tutor Systems in Language Instruction and Rehabilitation", M. Macedonia, & all, Frontiers in Psychology, 9:927, June 2018. https://doi.org/10.3389/fpsyg.2018.00927.*
• *"Quality-of-user-experience: a position paper", F. Hammer, & all, Quality and User Experience, Vol. 3, Number 9, 2018. https://doi.org/10.1007/s41233-018- 0022-0.*

• *Additional publications: https://silense.eu/outcomes/deliverables*

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Dominique Morche
Dominique.morche@cea.fr

COMPUTING

3eFERRO
ASCENT
BeforeHand
BigClouT
BRAIN-IoT
DECENTER
DEMETER
IoF2020
MB2020
MOS-QUITO
My-CUBE
NEURAM 3
NEUROTECH
QuCube
REMINDER
SIPOB-3D
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3eFERRO

Energy Efficient Embedded Non-Volatile Memory & Logic Based on Ferroelectric $Hf(Zr)O_2$

The 3eFERRO project involves developing memories based on a newly discovered material. This material consists of an ultra-thin (10nm) ferroelectric HfO_2 oxide layer, in which information can be stored in a highly energy-efficient way for future low power IoT devices.

https://www.3eferro.eu/

Keywords
Embedded Memory
Energy Efficient Circuits
FeFET
FeRAM
Ferroelectric
Internet of Things (IoT)
Logic-in-Memory
MCU

3eFERRO at a glance

42 months
Jan. 2018 > Jun. 2021

EC Programme
H2020 ICT

Project Coordinator
CEA-Iramis (FR)

Partners
DE: Jülich (Forschungszentrum Julich GMBH), NaMLab
FR: CEA-Leti, Institut des Nanotechnologies de Lyon - Ecole Centrale de Lyon (INL), STMicroelectronics
GR: Demokritos (National center for scientific research)
RO: NIMP (Institutul national de cercetare dezvoltare pentru fizica materialelor)
SW: Ecole Polytechnique Federale de Lausanne

Total budget
€ 3.99 m.

EC Contribution
€ 3.99 m.

Contract Number
780302

CEA-Leti in 3eFERRO

At CEA-Leti, we have successfully integrated the $HfZrO_2$ CMOS-compatible ferroelectric material from NaMlab into our 200mm pilot line. For the first time, it has been demonstrated that this material is fully Back-End Of the Line (BEOL) compatible with state-of-the-art performance for FeRAM memory applications, such as 30ns operating speed, together with outstanding >1011 cycling capability and promising data retention, even at 125°C.

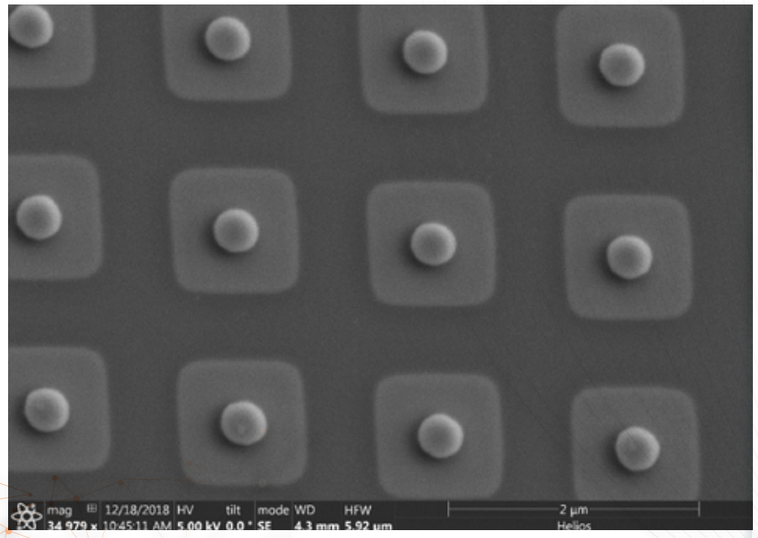
Based on first demonstrator run output and memory electrical characteristics obtained at single cell level, 16kbit arrays have been designed at CEA-Leti for optimized 1T-1C FeRAM functionality. Electrical readout is expected by mid-2020.

Objectives

Edge computing requires highly energy efficient microprocessor units (MCU) with embedded non-volatile memories (eNVM) to process data at the source, the IoT sensor node. eFLASH technology is limited by low write speed, high power and low endurance. Alternative fast, low power and high endurance eNVM could greatly enhance energy efficiency and allow flexibility for «finer grain» logic and memory. FeRAM has the highest endurance of all emerging NVMs. However, perovskite-based eFeRAM is incompatible with Si CMOS, does not easily scale and has manufacturability and cost issues.

We have introduced new ferroelectric material $Hf(Zr)O_2$ to make FeRAM a competitive NVM candidate for IoT. HfO_2 compatibility with Si processing will facilitate integration, improve manufacturability and allow better scaling. Different cell architectures based on capacitors or ferroelectric FETs will give unprecedented flexibility for “fine-grain” logic–in-Memory (LiM) circuits allowing data storage close to logic circuits, reducing the energy cost of data transfer and allowing smart gating for “normally-off” computing.

The project embraces four goals: i) Optimization of materials, ii) LiM design & architecture, iii) Integration of $Hf(Zr)O_2$-based NVM arrays and iv) Memory testing, validation & benchmarking.



Arrays of sub-micrometer size HfZrO2-based ferroelectric capacitors integrated above CMOS and processed at CEA-Leti.
© CEA-Leti

IMPACT

3eFERRO aims to meet the urgent needs of European integrated device manufacturers and key microelectronics manufacturers and will help them to confirm their leading position in the IoT market (innovative MCU component products). The project should place European stakeholders in “pole position” in the race for a universal memory combining a high storage density medium with high speed. This could bridge the gap in performance between processors and memories and contribute to future development of data-centric computation systems.

Publications

- *«Evaluation of Ferroelectricity in Si-implanted HfO_2 along Cycling», T. Francois, J. Coignus, L. Grenouillet, M. Barlas, B. Bessif, N. Vaxelaire, H.Boutry, M. Coig, E. Vilain, N. Rambal, J.-M. Pedini, Y. Morand, F. Mazen, E. Nowak, F. Gaillard, Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp203-204.*
- *«Ferroelectric HfO_2 for Memory Applications: Impact of Si Doping Technique and Bias Pulse Engineering on Switching Performance», T. Francois, J. Coignus, L. Grenouillet, J.-P. Barnes, N. Vaxelaire, J. Ferrand, I. Bottala-Gambetta, M. Gros-Jean, S. Jeannot, P. Boivin, P. Chiquet, M. Bocquet, E. Nowak, F. Gaillard, submitted to 2019 International Memory Workshop.*

TRL
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Laurent Grenouillet
laurent.grenouillet@cea.fr

Yves Quéré
yves.quere@cea.fr



ASCENT

www.ascent.network

Keywords
Nanowires
Silicon-On-Insulator (SOI)

ASCENT at a glance

48 months
May 2015 > Apr. 2018

EC Programme
INFRAIA-1-2014/2015

Project Coordinator
Tyndall National Institute (IR)

Partners
BE: Imec
FR: CEA-Leti

Total budget
€ 4.7 m.

EC Contribution
€ 4.7 m.

Contract Number
INFRA — 654384 — ASCENT

Quality of Service Provisioning and capacity Expansion through Extended-DSA for 5G

The aim of the ASCENT project is to provide access to universities in Europe (80%) and worldwide to some of the most advanced devices, technologies, models, electrical and physical characterization tools developed or available at three CEA-Leti, IMEC and Tyndall laboratories to further knowledge and research collaboration.

CEA-Leti in ASCENT

The ASCENT project has enabled CEA-Leti to develop or establish new collaborations with universities in Australia, Belgium, Germany, Greece, India, Ireland, Korea, Poland, Portugal, Romania, Spain and Sweden.

The main demands have involved (1) SOI wafers or data to develop DC, Noise, RF, ...models, (2) access to CEA-Leti models for design bench building, (3) access to advanced electrical and physical characterization tools to study university-developed new materials, devices and structures. The ASCENT project has enabled CEA-Leti to develop or establish new collaborations with universities in Australia, Belgium, Germany, Greece, India, Ireland, Korea, Poland, Portugal, Romania, Spain and Sweden.

The main demands have involved (1) SOI wafers or data to develop DC, Noise, RF, ...models, (2) access to Leti models for design bench building, (3) access to advanced electrical and physical characterization tools to study university-developed new materials, devices and structures.

Some examples of projects:
Modelling of short channel effects on Nanowires FDSOI devices with University of Mittelhessen (Germany).
Testing and modelling of 1/F noise on Nanowires FDSOI with University of Sejong (Korea).
Study of high frequency linearity of FDSOI with Indian Institute of Technology Gandhinagar (India).
Fabrication of a new concept of laser using PolySi with ultra small roughness with University of Cork (Ireland).
Cryogenic test of Finfet for SPICE modelling with EOLAS Design (Ireland).
Mobility spectrum in Nanowire SOI using magnetotransport by University of Western Australia.
Study of ceramic nanoparticles with Transmission Electron Microscopy by University of Aveiro (Portugal).
8 publications have been accepted to date and others are planned.

Objectives

The ASCENT consortium provides access to advanced nanoelectronics spanning finFET, Fully Depleted Silicon-On-Insulator (FDSOI) and flexible nanofabrication facilities. By delivering test structures and characterization data previously inaccessible to Europe's academic modeling and characterization community, ASCENT provides access to the latest nanoelectronics technologies.
The objective is to accelerate the development of advanced technology computer aided design models and tools through access to electrical characterisation facilities and data, that are validated and predictive for scales extending down to just a few nanometers in critical dimensions.
The project will also enable the systematic characterisation of physical and processing effects arising on length scales at and below 10 nm, and to develop design capabilities for technologies at these length scales.
Finally, ASCENT will make all project outputs (nanoelectronic test structures, electrical characterization access and data, TCAD models, compact models) easily accessible to the nanoelectronics community through a single access portal and openly available.



CEA-Leti experts provide access to equipment, facilities and unique know-how.
© CEA-P. Jayet

IMPACT

Project impact has been to develop new collaborations within and outside Europe to offer universities the opportunity to access the most advanced technologies and characterization tools.

Several active collaborations have been directly or indirectly established:
• Direct example: fabrication of a new concept of laser using PolySi with ultra small roughness with University of Cork (Ireland).

• Indirect example: Modelling of short channel effects on Nanowires FDSOI devices with University of Mittelhessen (Germany).

The latter excellent relationship has opened further discussions for a collaboration on organic transistors with CEA-Liten.

Publications

• *«Physics based Compact Model of Low-Frequency Noise for Gate-All-Around MOSFETs», B. Yi, G.- S. Yang, S. Barraud, L. Brevard, J.-W. Lee and J.-W. Yang; 26th Korean Conference on Semiconductors - Gangwon-do TB1 G6, 2019.*
• *«Low Frequency Noise Variability Analysis Depending on Epi-Source/Drain in GAA (Gate-All-Around) FET», G.-S. Yang, D.-H. Kim, D.-G. Park, S.-H. Kim, J.-C. Kim, S. Barraud, L. Brevard and J.-W. Lee ; 26th Korean Conference on Semiconductors - Gangwon-do TB1 G7, 2019.*
• *«Assessing the Correlation Between Location and Size of Catastrophic Breakdown Events in High-K MIM Capacitors», J. Muñoz-Gorriz, D. Blachier, G. Reimbold, F. Campabadal, J. Suñé, S. Monaghan, K. Cherkaoui, P.-K. Hurley, and E. Miranda; Trans. on Device and Materials Reliability, vol. 19, no. 2, June 2019, pp. 452-60 ; DOI: 10.1109/TDMR.2019.2917138.*
• *«Effect of traps-to-gate tunnel communication on C-V characteristics of MIS capacitors», A. Mazurak, J. Jasiński, B. Majkusiak; Microelectronic Engineering, 215 (2019), pp. 111011.1-5 ; DOI: 10.1016/j.mee.2019.111011.*
• *«Determination of border/bulk traps parameters based on (C-G-V) admittance measurements», A. Mazurak, J. Jasiński, B. Majkusiak; Journal of Vacuum Science & Technology B 37, 032904 (2019), pp. 032904.1-9; DOI: 10.1116/1.5060674.*
• *«Functionalization of SiO_2 Surfaces for Si Monolayer Doping with Minimal Carbon Contamination», M. van Druenen, G. Collins, C. Glynn, C. O'Dwyer and J.D. Holmes; ACS Appl. Mater. Interfaces, 2018, 10 (2), pp. 2191–201; DOI:10.1021/acsami.7b16950.*
• *«Williamson-Hall analysis in estimation of lattice strain in Bi1.34Fe0.66Nb1.34O6.35 prepared by the sol-gel method», S. Devesa, A.-P. Rooney, M.-P. Graça, D. Cooper, L.-C. Costa; submitted to Materials Science and Engineering B.*

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Olivier Faynot
olivier.faynot@cea.fr



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BeforeHand

Objectives

The project aim has been to establish the foundations of new technology to be implemented in Electronic Smart System (ESS) networks exploiting the capability of phase-change materials to process and store data in the same physical location, specifically focusing on automotive applications. The ESS of the future should be able to sense its environment, store locally and process information as well as communicate with other objects in a network. The BEFOREHAND project targets production of processing/storage devices by developing new material combinations with the best material trade-off and benchmarked for automotive applications. A test vehicle will be used to compare the different materials. After assessment of the best material combination, a demonstrator with processing/storage capability will be implemented. Full appraisal of the demonstrator is planned on completion of the project. Integration in an embedded chip environment for automotive applications, along with scalability and reliability issues, will be evaluated. The project outcomes will be made public and used to schedule the first chip with embedded state-of-the-art technology to be implemented in the automotive sector; a direct impact on the Internet of Things (IoT) market is expected. BEFOREHAND will ensure practical realization of such a novel technological computing paradigm. It is a project that deeply involves material development, device preparation and functionality in relation to memory devices as well as data processing devices.

www.beforehand.eu

Keywords
Memory
Multilayers
Phase change

BeforeHand at a glance

36 months
Jan. 2019 > Dec. 2021

EC Programme
H2020 -ICT 2018 2020

Project Coordinator
Forschungsverbund Berlin Ev (DE)

Partners
DE: Forschungsverbund Berlin Ev
FR: CEA-Leti, Centre National de la Recherche Scientifique
IT: Consiglio Nazionale delle Richerche, STMicroelectronics SRL, Universita degli Studi di Milano Bicocca, Universita degli Studi di Roma Torvergata
NL: Rijksuniversiteit Groningen

Total budget
€ 0.4 m.

EC Contribution
€ 0.4 m.

Contract Number
824957

Boosting Performance of Phase Change Devices by Hetero- and Nano-structure Material Design

The aim of the BEFOREHAND project was to develop chalcogenide-based heterostructures for processing and storage devices for embedding in automotive Internet of Things (IoT) smart systems.

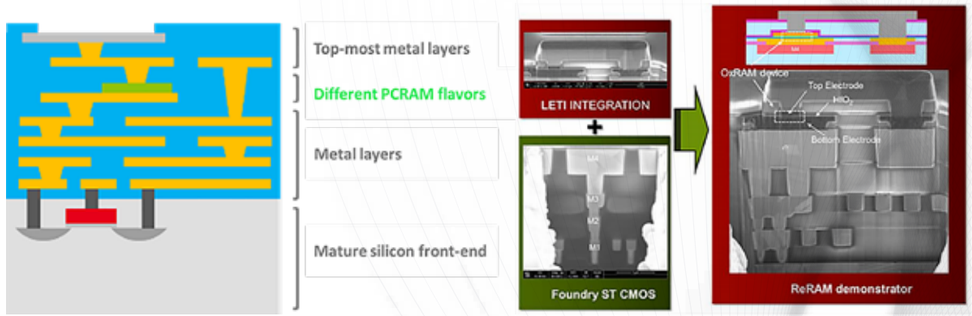
CEA-Leti in BeforeHand

The role of CEA-Leti has been to:

- Develop a single cell vehicle to enable the electrical characterization of multilayered structures developped by BEFOREHAND partners
- Define and transfer to partners PDI, CNR-IMM, URTOV, UGRO the most promising multilayer stacks on a 200 (or 300 mm) deposition tool. Composition and morphologic characterization will be carried out on deposited stacks (RBS, WDXRF, XRD, FTIR, TEM) and resistivity vs temperature will be used to characterize crystalline to amorphous transition
- Fabricate the final demonstrator, integrating an optimized Phase Change Memory (PCM) heterostructure into CMOS wafers (130 nm node) above Metal 4 level. CEA-Leti plans to use its Memory Advanced Demonstrator platform to enable the fabrication of single devices as well as 1T1R and kbit up to Mbit arrays.

Results

During the first year of the project, CEA-Leti has developed the single cell vehicle with Partner IMM. This involved fabricating small TiN-based heaters using e-beam lithography, reactive ion etching and chemical mechanical polishing. Heaters as small as 40nm in diameter were fabricated on 200mm wafers and delivered to the BEFOREHAND consortium for subsequent multilayer deposition. Complete devices are now under electrical testing.



Schematic cross view of MAD test vehicle and example of Leti's ReRAM integration.
© CEA-Leti

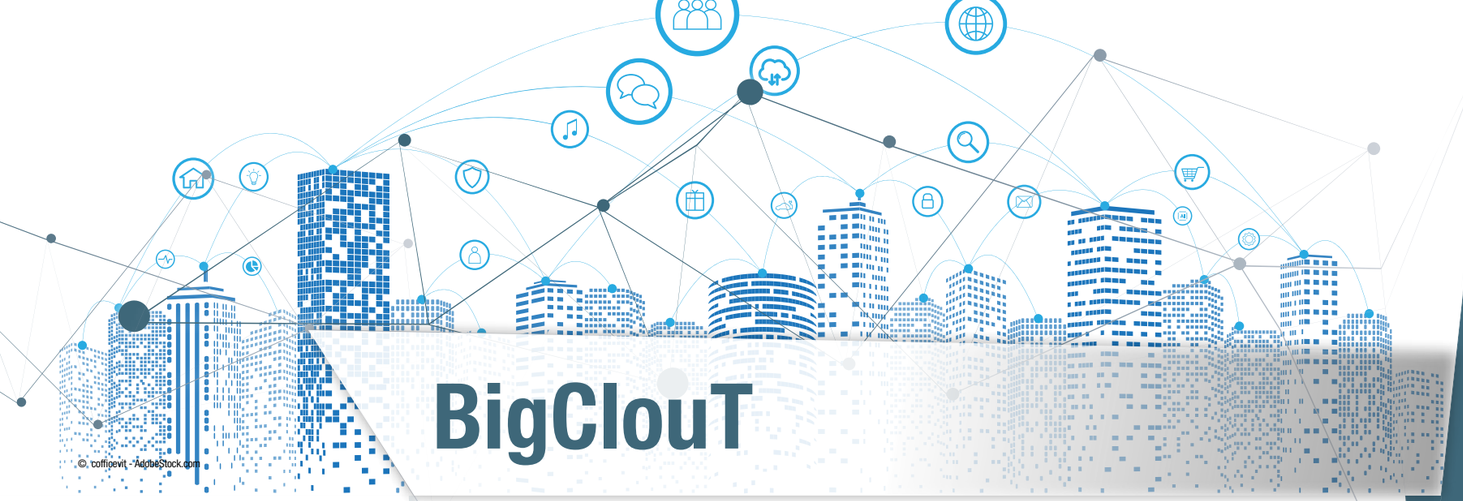
IMPACT

Strengthening of Europe leadership towards the development of PCM for automotive applications. Chalcogenide heterostructures developed in the BEFOREHAND project for processing/storage devices for embedding in automotive IoT smart devices have a disruptive future innovative potential, which may lead to breakthroughs at different technology levels from basic research beyond the state of the art to products themselves.

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Marie-Claire Cyrille
marie-claire.cyrille@cea.fr

Yves Quéré
yves.quere@cea.fr



BigClouT

Big data meeting Cloud and IoT for empowering the citizen clout in smart cities

The BIGCLOUT project provides a unified urban data platform allowing quick and easy access to a variety of city-based data sources (IoT devices, legacy platforms, data generated by citizens, etc.) and a toolbox for analyzing collected big data, extracting high-level information and providing customized recommendations.

http://bigclout.eu

Keywords
Big data
Edge processing
Europe
Internet of Things (IoT)
Japan
Smart city
Smart tourism

BigClouT at a glance

36 months
Jul. 2016 > Jun. 2019

EC Programme
H2020-EUJ-2016

Project Coordinator
CEA-Leti (FR), NTT East (JP)

Partners
FR: Absiskey CP, Grenoble-Alpes Métropole
GR: NTU Athens
JP: Keio University, National Institute of Infomatics, NTT East, NTT R&D, University of Tsukuba
IT: Engineering Ingegneria Informatica Spa
UK: BristolIsOpen Limited, Lancaster University

Total budget
€ 2.7 m. (1.35 m. EU + 1.35 m. JP)

EC Contribution
€ 1.5m. (+ 1.5 m.contribition from Japanese NICT)

Contract Number
723139

Objectives

The world is facing a number of critical challenges including global warming, economic crisis, security threats, inequality, natural disasters and aging societies. Urban areas are particularly affected, given that the world population is increasingly concentrated therein. ICT solutions have the potential to change the world and enhance the quality of life and security of its inhabitants. The IoT, the Cloud and Big Data are today's key enablers for increasing efficiency of shared urban infrastructure, economic and natural resources.
The overall concept of the BIGCLOUT project is to provide a city with an analytic mind by creating distributed intelligence that can be located throughout the urban networks. The unprecedented number of connected things and their relevant big data raise new technical challenges in terms of interoperability, scalable and online data processing, actionable knowledge extraction, self-management, security and privacy. The BIGCLOUT project is drawing together the necessary resources and knowledge provided by prestigious European and Japanese institutions for tackling these challenges.
BIGCLOUT has been leveraging the results of the CLOUT project to advance them by several steps, especially through added distributed intelligence based on edge computing principles, big data analytic capability and self-awareness property.
The BIGCLOUT platform is being deployed and validated in four project pilot cities, namely Grenoble, Bristol, Tsukuba and Fujisawa. The project is granting special importance to the involvement of citizens during the entire project life through use case definitions to validation. It also has the ambitious aim of creating a community of external end-users building their own applications/business on top of BIGCLOUT tools and its platform. This includes keeping this community alive during the project and beyond to ensure the sustainability of CLOUT and BIGCLOUT outcomes.

CEA-Leti in BigClouT

CEA-Leti is coordinating the European side of the project. On the technical level, the Institute is providing its IoT data collection and processing platform, sensiNact. This comprises a software platform for collecting, processing and redistributing IoT data related to improving people's quality of life via various applications provided by domains such as smart city, smart home, smart transport, etc. It provides programming interfaces allowing different ways to access data (on-demand, periodic, historic, etc.) as well as application development and deployment for quickly and easily building innovative applications on top of the platform.

The platform has been used in the project as an enabler for accessing heterogeneous data collected by sensors and legacy data platforms. It is enhanced with self-management properties and intelligence at gateway level by additional local processing techniques proposed by the project. It is being implemented in a local pilot use case in Grenoble; this involves providing useful information (mobility, restaurants, events, etc.) and recommendations to employees of the city's Inovallée industrial area. CEA-Leti is also contributing its IoT service creation tool, sensiNact Studio, and is complementing this tool with a dependability property to allow IoT applications to be reliably and securely developed.

In parallel with the other pilot deployments in European partner cities and in Japan, the project is demonstrating a global smart city platform concept in relevant environments, which will enhance its TRL level.



IMPACT

- Technical: providing the foundations (generic architecture and its reference implementation) of an urban data platform.
- Societal: improving the quality of life of citizens and tourists in four project pilot cities, namely Grenoble, Bristol, Fujisawa and Tsukuba.
- Economic: providing a data-driven business model adapted to a multi-stakeholder context such as the urban environment.
- Global: reinforcing global collaboration in the smart city domain by creating the Urban Technology Alliance: www.urbantechnologyalliance.org.

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Levent Gürgen
levent.gurgen@cea.fr

Dider Belot
didier.belot@cea.fr



BRAIN-IoT

model-Based fRamework for dependable sensing and Actuation in INtelligent decentralized IoT systems

The BRAIN-IoT project is ensuring interconnection of several Internet of Things (IoT) platforms, while enforcing privacy and data ownership. Development of model-based tools and methods, together with open semantic models, is facilitating development of innovative, tightly integrated IoT and Cyber-Physical Systems (CPS) solutions.

http://www.brain-iot.eu

Keywords
Cyber Physical Systems
Cyber-Security
Internet of Things
Smart Cities

BRAIN-IoT at a glance

36 months
Jan. 2018 > Dec. 2020

EC Programme
H2020-IOT-2016-2017/H2020-IOT-2017

Project Coordinator
LINKS Foundation (It)

Partners
DE: Eclipse Foundation Europe GmbH, Siemens AG
ES: Empresa Municipal de Aguas de la Coruna (Emalcsa), Improving Metrics, Robotnik Automation SLL
FR: Airbus Cybersecurity, CEA, Institut de l'Audiovisuel et des Telecommunications en Europe, STMicroelectronics (Grenoble 2) SAS, Université Grenoble Alpes,
IT: Links Foundation
UK: Paremus Ltd

Total budget
544 Homme/mois pour un budget total de € 4.9 m.

EC Contribution
€ 4.9 m.

Contract Number
780 089

CEA-Leti in BRAIN-IoT

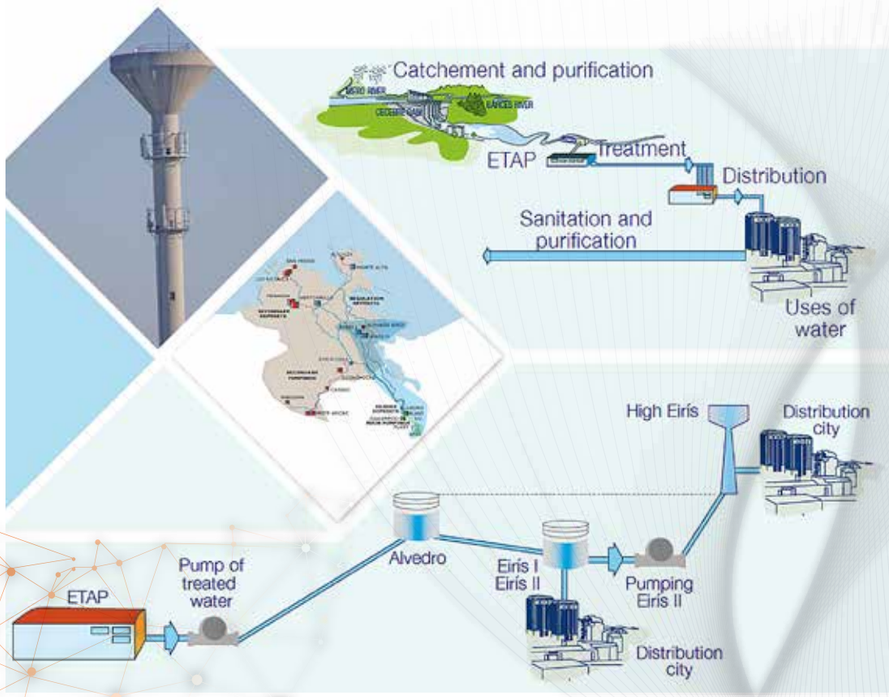
CEA-Leti's sensiNact platform is based on and open source software model that creates developer ecosystems for different application domains at national and international levels. It accompanies relevant stakeholders (small and large industries, cities, etc.) in their digital transformations. SensiNact is an open source project within the Eclipse Foundation, which brings together a large, active worldwide community of developers, especially in the IoT domain. On top of sensiNact, CEA-Leti has created an IoT application development, deployment and management tool that can connect to IoT platforms and provide resources for building services and applications by mashing up IoT device level services. The Institute is promoting the platform for usage by a large portfolio of public, private, national and international partners. The BRAIN-IoT project provides added value to the platform through services and features that are promoted through the Institute's industrial partners. More specifically, BRAIN-IoT enriches sensiNact with security and dependability properties, which are essential in the IoT context. The goal is to make IoT applications reliable and secure through design.

• Correct construction methodology builds sensiNact applications using a model-driven verification method.

• BRAIN-IoT integrates decentralized security and privacy capabilities including authentication, authorization and accounting for the overall distributed fog environment and end-to-end security for IoT data-flows. A cross-platform framework facilitating adoption of privacy control policies is also being developed in BRAIN-IoT.

Objectives

BRAIN-IoT is establishing a framework and methodology that support smart, autonomous, cooperative behaviors of heterogeneous IoT platforms, which are closely interacting with Cyber-Physical Systems (CPS). BRAIN-IoT implements strongly dynamic federations of heterogeneous IoT platforms, mechanisms enforcing privacy and data ownership policies along with open semantic models enabling interoperable operations, exchange of data and control features. The project will also offer model-based tools to facilitate development of innovative, tightly integrated IoT and CPS solutions.



CEA validate Brain-IoT developments with EMALCSA, the large-scale water network of La Coroña (Spain).
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IMPACT

The BRAIN-IoT project is mainly targeting impacts from the two areas of application:
Smart water management: 5% reduction of water lost in leaks, 5% reduction in overall water consumption, 5% more efficient energy usage for water pumping, etc.
Service robotics in factory warehouses: greater warehouse security by reducing accident rates by 10%, reduced delivery time by 15%, autonomous transportation of goods without carbon and fuel, etc.
In addition, the BRAIN-IoT project is contributing to standardization organizations such as OSGi Alliance, W3C Web of Things, OMG MARTE 2.0, among others.

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Christian Fabre
christian.fabre1@cea.fr

Dider Belot
didier.belot@cea.fr



DECENTER

https://www.decenter-project.eu/

Keywords
Blockchain
Cross-border applications
Distributed artificial intelligence
Europe
Fog computing
Internet of Things (IoT)
Korea
Resource federation
Smart cities

DECENTER at a glance

36 months
Jul. 2018 > Jun. 2021

EC Programme
H2020-EUK-2018

Project Coordinator
EU Coordinator: Fundazione Bruno Kessler (FBK);
Korean Coordinator: Korea Electronics and Technology Institute (KETI)

Partners
ES: Atos Spain SA, Robotnik Automation SLL
FR: CEA-Leti
IT: Comune di Trento
KR: Daliworks, Gluesys, LG U+, Seoul National University
SI: Univerza v Ljubljani

Total budget
€ 4.6 m.

EC Contribution
€ 4.6 m.

Contract Number
815141

Decentralized Technologies for Orchestrated Cloud-to-Edge Intelligence

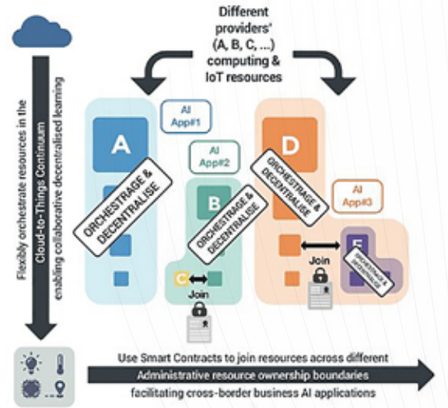
The DECENTER project will provide a collaborative environment, in which multiple stakeholders (Cloud and Internet of Things providers) can securely share and harmoniously manage resources. DECENTER is deploying resources, such as innovative decentralized Artificial Intelligence (AI) algorithms and models, across multiple tiers of its infrastructure and federated clouds.

CEA-Leti in DECENTER

The DECENTER project provides the opportunity for CEA-Leti's Internet of Things (IoT) platform, sensiNact, to be leveraged by innovative, beyond SOTA, technical features such as distributed orchestration of edge devices and intelligence in the edge approach. It gives sensiNact the opportunity to validate those features within project pilots in close to real-life conditions from various application domains such as smart home and smart city, thus increasing its maturity (e.g. TRL) level. The platform validation results will help CEA-Leti to determine the robustness of the approach and to clarify issues related to social acceptance, economical context, technical challenges, target activity sectors, etc. CEA-Leti will commercially exploit the platform with its industrial partners. The core of the sensiNact platform is provided as open source, while the tools and libraries for bringing intelligence and the IoT service creation tool, sensiNact Studio, are value added extensions. In addition, CEA-Leti will exploit the project results within the relative initiatives such as the Urban Technology Alliance, a smart city-related testbed-oriented consortium, which it is leading with its European, Japanese and Korean partners.

Objectives

The emerging spring of Artificial Intelligence (AI) will enable innovative applications exploiting the myriad of connected sensors and appliances embedded in every corner of modern life. Currently, AI requires high computational resources only available in high-performance data centers. Designing an architecture capable of securely processing this unprecedented amount of remotely sensed and potentially sensitive data, and conveying timely responses to pervasive configurable actuators is a non-trivial endeavor requiring the cooperation of multiple parties.
To address these challenges, the DECENTER project aims to build a robust Fog Computing platform, covering the whole Cloud-to-Things Continuum, that will provide AI application-aware orchestration and provisioning of resources. The project enriches existing Cloud and IoT solutions with advanced capabilities to abstract features and process data closer to where it is produced. DECENTER is establishing a collaborative environment, in which multiple stakeholders (Cloud and IoT providers) can securely share and harmoniously manage resources in dynamically created multi-cloud/edge federated environments. Cross-border infrastructure federation is ensured by Blockchain-based Smart Contracts defining customized Service Level Agreements used to commit execution of verified workloads across multiple, potentially remote administrative domains. Through such novelties, DECENTER will unlock the potential of innovative decentralized AI algorithms and models by deploying them across multiple tiers of the infrastructure and federated clouds.
The project follows a lean implementation methodology and validates its concept with real-world pilots executed in urban, industrial and home environments. With its approach, DECENTER targets the emergence of innovative digital businesses, thus providing a competitive advantage to EU and Korean industry and fostering cross-border collaboration.



SensiNact platform validation results in DECENTER helps CEA-Leti to determine its robustness, social acceptance, economical context and target activity sectors.
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IMPACT

Project Impacts
- Concrete implementation of interoperable and reliable combined cloud/IoT solutions to support robust AI applications.
- Credible demonstrations based on cross-border business and/or societal AI applications on the cloud platform developed.
- Joint contributions to international standardization and/or forum activities.

Business and Industrial Impact
- DECENTER will take advantage of existing IoT and Cloud platforms, extending their functionalities and improving their response time.
- DECENTER will go beyond the state of the art of current technologies and offerings to provide a next generation platform for improving industry solutions.
- DECENTER will propose new business models that will be entirely applicable to the current market situation in order to exploit the full potential of the proposed solution.
- DECENTER will prompt emergence of innovative digital businesses in the global market, thus providing a competitive advantage to the European and Korean companies that will follow its vision and adopt its platform.
- DECENTER aims to facilitate integration by proposing a highly decentralized infrastructure, in which the processing and storage capabilities of the cloud are moved closer to the things, by means of the fog computing approach that the project is willing to embrace.

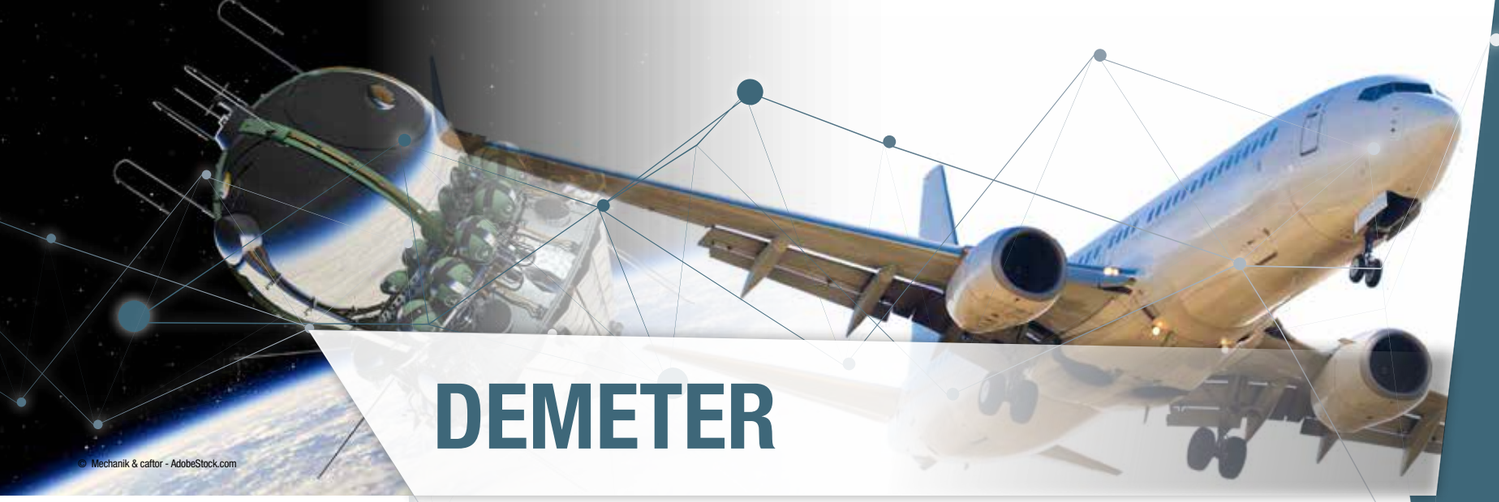
Societal Impact
- DECENTER will strength adoption of Edge and Cloud computing both in Europe and Korea. As pointed out in the EC Cloud computing strategy, increased adoption of the Cloud will lead to significant increases to European DGP, job creation and energy efficiency.
- DECENTER will try to complete target use cases derived from societal challenges related to safe home and around. DECENTER will propose an advanced decentralized computing structure supporting distributed AI based on constraints in terms of time (i.e. acceptable latency), resource availability (network, computing) and privacy. Data will be collected from a variety of heterogeneous sensors and cameras.
- DECENTER will foster the adoption of the IoT model that, combined with the Cloud model, will support European and Korean business growth and success.

Publications
Press release
CEA-Leti: http://www.leti-cea.com/cea-tech/leti/english/Pages/What's-On/Press%20release/CEA-Leti-Middleware-Will-Be-Core-Of-Fog-Platform-for-Decentralized-Cloud-To-Edge-AI.aspx

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Levent Gürgen
levent.gurgen@cea.fr

Dider Belot
didier.belot@cea.fr



DEMETER

DEMETER
http://demeter-eniac.eu

Keywords
Avionics
Field-Programmable Gate Array (FPGA)
Harsh environment
Multiprocessor
SoC
Space

DEMETER at a glance

38 months
Nov. 2015 > Dec. 2018

EC Programme
ENIAC-2013-2 (Chapter 6 Design technologies, Chapter 7 Semiconductor process and integration)

Project Coordinator
STMicroelectronics Grenoble2 SAS (FR)

Partners
FR: ADICSYS, Airbus Defense and Space, Airbus Group, CEA-Leti, CEA-List, CNES, ESA, IROC Technologies, NanoXplore, ONERA, SAFRAN, STMicroelectronics Crolles2 SAS, STMicroelectronics Grenoble2 SAS, SYSGO, Thales Alenia Space France, Thales Avionics, Thales Research & Technology, Voox Technologies
GR: Integrated Systems Development
IT: Politecnico di Torino, Thales Alenia Space Italy
PL: Astri Polska

Total budget
€ 19.30 m.

EC Contribution
€ 2.85 m. (+ 4.69 m. national contributions)

Contract Number
ENIAC Joint Undertaking N°621282

Deep Submicron System-on-Chip for Harsh Environment Applications using European Technologies

The DEMETER project is focusing on two principal design areas involving digital integrated circuits for use in aggressive environments: 1/ design of a prototype of the next generation rad-hard FPGA for space applications and, 2/ analysis and proposal of novel architectures for system-on-chip avionics.

CEA-Leti in DEMETER

CEA-Leti contributions to the DEMETER project are centered on enabling efficient multiprocessor chip-based systems for avionics and, in particular, the key challenge of **best using available computing power, while ensuring the necessary time criticality**.

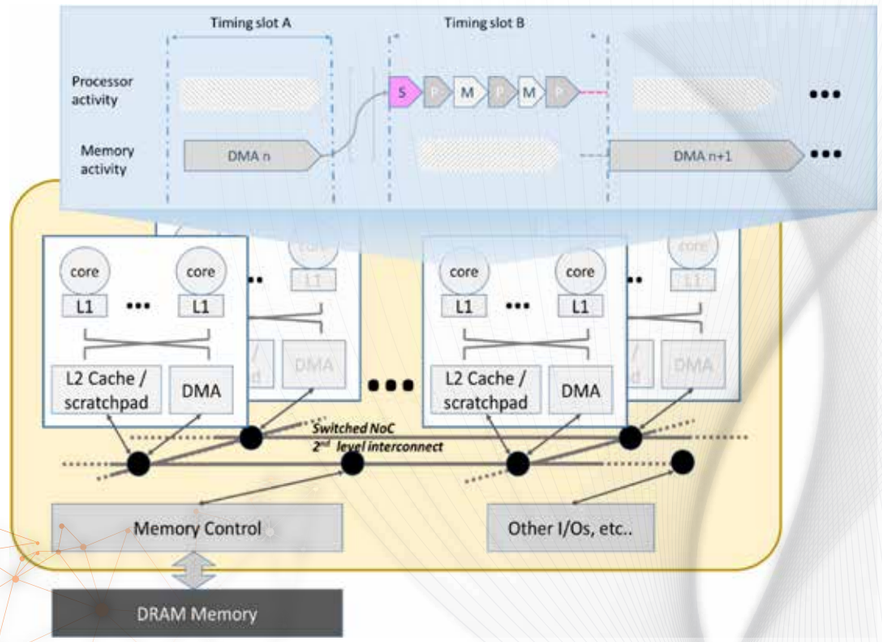
Several existing proprietary and third party IPs have been initially assessed in relation to the avionic context. In particular, the feasibility of implementing the project partners' IPs has been verified and place-and-route trials of a 64-bit RISC-V processor have been conducted in FDSOI 28nm technology. These have revealed 1+GHz performance without any specific need for optimization.

This work has been complemented by in-depth analysis of time predictability issues in the interconnection IPs of modern cluster-based, multiprocessor chip-based systems via theoretical studies and models including network calculus. A novel approach has been proposed to curtail uncertainties in guaranteed maximum execution time boundaries. This relies on a double-buffered approach that de-correlates processing in local memories from dedicated DMA data exchanges between memories.

A support for mixed criticality has also been proposed with the design of a specific IP able to work as a classical cache for "best effort" workloads and as a local memory for time-critical tasks. This IP is configurable and its memory space can be split into these two modes to support mixed critical workloads. Integration of this IP into a 16-processor (4-cluster) platform has provided a 40% improvement in execution time for a Haar transform algorithm compared to a conventional cache approach.

Objectives

DEMETER offers a new systems-on-chip platform for systems capable of operating in aggressive environments. The platform enables ASIC, ASSP and FPGA research and development. The demonstrators are simplified radi-hard (radiation-hardened) FPGAs and multiprocessor platforms for avionics involving ARM and RISC-V cores.
There is state-of-the-art production capability in Europe for equipment and wafer fabrication, but many Integrated Circuits (ICs) used on the old continent are developed and manufactured elsewhere or use non-European fabrications.
In space and aggressive environment markets, e.g. avionics, Europe can and must compete with American suppliers (Honeywell, BAE, Aeroflex, Actel and Xilinx). However, with the proposed framework in place, European IC technology can expand to global level.
Aggressive environments represent a niche market, but they can lead to new or emerging technologies. It is important to note that, based on ever smaller semiconductor process technologies, applications become increasingly sensitive to radiation and other constraints and therefore fall progressively into the aggressive environment category.
T aeronautics market enables applications, such as space, avionics, transport and energy systems, to be developed with different levels of hardening. Finally, automotive market can also benefit from this trend and it contributes the level of reliability associated with its multi-million unit production levels.
Concentrating mainly on digital IC, the DEMETER project aims are to support development of the next generation of advanced rad-hard FPGAs (NG-FPGA-ULTRA) in 28nm or beyond and to anticipate the avionic certification issues involving multi-core architectures.



CEA efficient multi-processor chip-based system for Avionic applications.
© CEA-Leti

IMPACT

DEMETER is one of several projects targeting the design of the next product generation to replace current 65nm FPGAs. The project prototype allows assessment of sub-block performance characteristics.
Regarding avionic chip-based systems, the DEMETER project has allowed identification of showstoppers in currently available ARM-based architectures and has proposed several realistic developments of conventional multiprocessor architectures for adaptation to avionic constraints. However, no European industrial has positioned itself on this market to date.

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Jérôme Martin
jerome.martin@cea.fr

Dider Belot
didier.belot@cea.fr



IoF2020

Internet of Food & Farm 2020

The IoF2020 project is dedicated to accelerating adoption of IoT for securing sufficient, safe, healthy food and to strengthening competitiveness of farming and food chains in Europe. It will consolidate Europe's leading position in the global IoT industry by fostering a symbiotic ecosystem of farmers, food industry, technology providers and research institutes.

http://iof2020.eu/

Keywords
Agri-Food
Business innovation
Data-driven farming
Food chain
Food security
Internet of Things (IoT)
IoT business integration
Large scale pilot
Precision farming
Smart farming

IoF2020 at a glance

48 months
Jan.2017 > Dec.2020

EC Programme
H2020-IOT-2016-2017

Project Coordinator
Wageningen University and Research

Partners
FR: CEA-LETI is mainly involved in Wine optimisation use case in Bordeaux with the partners :
Bordeaux INP - IMS Laboratory
Denis Dubourdieu Domaines
ISVEA
STMicroelectronics
Vinidea

Total budget
€ 30 m.

EC Contribution
€ 30 m.

Contract Number
731884

Objectives

The IoF2020 consortium of 73 partners, led by Wageningen UR and other core partners of previous key projects such as FIWARE and IoT-A, is leveraging the ecosystem and architecture that was established in those projects.
The heart of the project is formed by 19 use cases grouped into 5 trials with end-users from the arable, dairy, fruit, vegetable and meat verticals and IoT integrators, which are demonstrating the business case involving innovative IoT solutions in multiple application areas.
A lean multi-player approach focusing on user acceptability, stakeholder commitment and sustainable business models is boosting technology and market readiness levels, and advancing end-user uptake to the next stage.
This development is being enhanced by open IoT architecture and an infrastructure of reusable components based on existing standards along with a security and privacy framework.
In anticipation of extensive technological developments and emerging challenges for farming and food, the 4-year project remains buoyant through dynamic budgeting and adaptive decision-making by an implementation board made up of representatives from key user organizations. A 6 M€ mid-term open call will allow for testing intermediate results and will extend the project based on technical solutions and test sites.
A coherent dissemination strategy for use case products and project lessons supported by leading user organizations is ensuring high market visibility and a steeper learning curve.
The IoF2020 project is paving the way for data-driven farming, autonomous operations, virtual food chains and personalized nutrition for European citizens.

CEA-Leti in IoF2020

CEA-Leti is providing its IoT data collection and processing platform, sensiNact, which allows interoperable services and applications to be developed in the smart farming field. SensiNact is an open source eclipse platform, which is currently used and investigated by several European, Korean and Japanese projects such as ACTIVAGE, DECENTER, BIGCLOUT, etc. The platform's usefulness has already been confirmed in various application scenarios in these projects including, but not limited to, smart home, smart city and smart transport fields. The IoF2020 project is offering us the chance to validate this European platform in the smart farming fields through its large-scale deployment.

CEA-Leti is one of the main technological providers for the use case (UC3.2) involving major wine optimization. This case uses the sensiNact IoT technology to monitor real-time weather, vine and cellar conditions. The collected information is used to determine phenological stages, detect diseases in their early stages and demonstrate the potential benefits of innovative cultivation methods.

The sensiNact platform is being used to aggregate data from several IoT devices deployed in five vineyards and four wineries in the Bordeaux area of France. A wide variety of physical devices, such as weather and metering stations, have been connected to a central LORA low-power server and wide area networking protocols (LORAWAN). SensiNact is ensuring steady measurement collection and redistribution by maintaining an MQTT-based connection to LORA server. Data is being redistributed via a dedicated REST API. Finally, all measurements are being safely stored in a Cassandra database and are accessible by sensiNact's REST API.


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IMPACT

• Technical: providing the foundations of an interoperability framework in the IoT with reference implementations for protocols such as MQTT. The new generation of farmers are taking advantage of user-centric devices integrated into their work flow (e.g. smart phones and tablets) as well as significantly increased usage of cyber physical systems such as service robots for professional usage.

• Societal: IoT potentials are promising disruptive innovations and contributions to the key challenges confronted by society: e.g. how to avoid waste, enhance consumer health and maximize productivity in a world that is suffering from land and especially water shortage.

• Economic: providing a data-driven business model, which increases the efficiency of agricultural production and improves product quality and safety.

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Levent Gürgen
levent.gurgen@cea.fr

Dider Belot
didier.belot@cea.fr



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MB2020

MONT-BLANC

http://montblanc-project.eu

Keywords
Big data
High Performance Computing (HPC)
Processor
SoC

MB2020 at a glance

36 months
Dec. 2017 > Nov. 2020

EC Programme
H2020-ICT-2016-2017

Project Coordinator
Bull SAS (FR)

Partners
DE: Forschungszentrum Jülich
ES: Barcelone Supercomputing Center, SemiDynamics
FR: Bull SAS, CEA, Kalray S.A.
GB: ARM

Total budget
€ 10.13 m.

EC Contribution
€ 10.13 m.

Contract Number
779877

Mont-Blanc 2020

The main aim of the Mont-Blanc 2020 project is to develop processor architecture for use in high-performance computing systems in Europe. This architecture will target a high number of operations per second and low power consumption.

Objectives

The MB2020 project is paving the way towards a future low-power European processor for Exascale computing (50 Gflops per watt at package level, including compute System on Chip (SoC), memories and NIC interface) with a second generation planned in 2022. This is being achieved by:
- Designing low-power system-on-chip architecture targeting Exascale
- Implementing new critical building blocks (IPs) and providing a blueprint for first generation implementation
- Delivering an initial proof-of-concept demonstration of its critical components in real-life applications
- Investigating how to re-use building blocks to provide markets other than HPC with methodologies that ensure better time predictability, especially for mixed-critical applications, in which guaranteed execution and response times are crucial.

The three key challenges to achieving desired performance at low power are:
- A processing unit that provides efficient, exploitable compute capabilities
- An innovative on-die interconnect that can supply enough bandwidth to the processing units with minimum energy consumption
- A high-bandwidth and low power memory solution with sufficient capacity and bandwidth for Exascale applications.

CEA-Leti in MB2020

In the Mont-Blanc 2020 project, CEA-Leti is mainly working on integrating the processor SoC and demonstrating processor architecture performance.

CEA-Leti is hosting and leading validation and demonstration activities on its hardware emulator. Hardware emulation offers the opportunity to assess the design on a large number of application test-cases, while reducing the total time taken in RTL simulation. This methodology is key to verifying the Mont-Blanc 2020 components and deducing its related performance. The project is strengthening CEA-Leti's position in the European ecosystem of processor design for Exascale computing.

CEA-Leti is also contributing to the low-power IP design, definition of the SoC power management strategy and analysis of solutions for 2.5D integration including SoC partitioning and floorplanning.

During the first year of the project, CEA-Leti has developed a clock generator with IR-drop detection and prevention capabilities.

The second year of the project is focusing on designing a die-to-die link for 3D short-range communication including self-calibration capabilities. With regard to emulation, integration of the first IPs has started; the objective is to be initially capable of injecting the application traces generated from a simulation platform, thereby stressing the on-chip network to allow assessment of memory hierarchy performance. CEA-Leti is also proposing and on-die power supply solution to support the global power management strategy.


Emulation platform at CEA-Leti.
© CEA-Leti

IMPACT

The processor is the central component of all systems but Europe is currently purchasing all its processors from non-European companies. This complete dependency on extra-European companies is placing a huge burden on the European economy. The Mont-Blanc 2020 project is developing the technological basis for follow-up commercial processors targeting HPC, Big Data and other markets. The European Processor Initiative (EPI) project is leveraging the technology developed by Mont-Blanc 2020.

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Romain Lemaire
romain.lemaire@cea.fr

Dider Belot
didier.belot@cea.fr



MOS-QUITO

MOS-based Quantum Information Technology

The MOSQUITO project took one of the most promising approaches to quantum computing and implemented it on an industrial CMOS platform. The first important step was accomplished within 3 years: building the first CMOS-based qubit, which is the basic building block of a quantum computer.

www.mos-quito.eu

Keywords
CMOS
Quantum
Qubit
Silicon

MOS-QUITO at a glance

36 months
Apr. 2016 > Apr. 2019

EC Programme
H2020 - ICT

Project Coordinator
CEA-Leti (FR)

Partners
CH: EPFL
DK: University of Copenhagen
FI: VTT
GB: Hitachi Cambridge Lab, University College London
IT: CNR

Total budget
€ 3.9 m.

EC Contribution
€ 3.5 m.

Contract Number
688539

CEA-Leti in MOS-QUITO

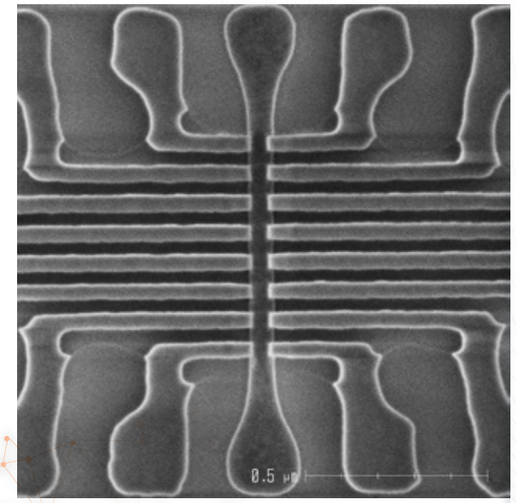
On the MOSQUITO project, CEA-Leti's role was to fabricate linear arrangements of Gate-defined Quantum Dots along Si nanowires to demonstrate spin quantum bits on a CMOS platform. A full mask set (19 DUV levels and 4 EBeam databases) was coupled to a process flow, closely derived from an SOI NanoWire FET fabrication sequence, to deliver a batch of 300mm wafers with multiple-gate test devices. A new patterning strategy, relying on misalignment-tolerant hybrid DUV-EBeam lithography, was developed simultaneously to i/ achieve 65nm Gate pitch with good dimensional control, ii/ save EBeam writing time, and iii/ respect the density rules compatible with Back-End-Of-Line processing in an industrial fabrication facility. This high throughput approach allowed provision of more than a hundred thousand testable devices in a given batch. Our devices were tested at cryogenic temperatures by the consortium partners to control coherently the spin state of the elementary charges confined by the Quantum-Dot-defining Field-Effect Gates. This led to the first demonstration of a hole spin qubit in silicon and to the first experimental demonstration of all-electrical control of single electron spins in silicon. Furthermore, single-shot readout schemes, based on Gate reflectometry, were implemented for fast detection (~1µs) of charge state variations in Quantum Dots. In summary, the main outcome of this project was establishing a design and fabrication platform for prototype devices, which are simultaneously competitive with academic state-of-the-art semiconductor spin qubits and compatible with CMOS foundry processing.

Objectives

A qubit device embeds a quantum two-level system that encodes an elementary bit of quantum information. Our type of qubit relies on a spin degree of freedom of an electronic or nuclear type. It was recently shown that a spin in silicon can hold a bit of quantum information for very long periods. This made it an attractive option for building a quantum computer. A number of silicon-based spin qubits had already been proposed and had been experimentally demonstrated in academic research laboratories. The main aim of this project was to show that such high-fidelity spin qubits can be manufactured in silicon using industry-standard CMOS processes at a large-scale nanofabrication facility. Our approach was based one a single, versatile building block, which could be tuned to operate under different regimes to give up to five different qubit productions in one device. The performance of these different qubit was benchmarked against key criteria such as fidelity, speed and suitability for large-scale integration.

Design and modelling was implemented alongside measured performance metrics to identify optimum large-scale architectures, while control tools were developed for application to scaled qubit arrays. We also developed a toolkit of CMOS-based conventional devices (low noise amplifiers, RF generators and multiplexers) for use as low-temperature peripheral electronics to ensure better control and readout. Sharing the same CMOS technology, qubits and peripheral electronics could even be positioned close to each other on the same chip. This unique opportunity could be particularly helpful for developing fast readout circuitry.

Summary of main project goals:
- Fabrication of spin qubit devices using 300-mm SOI technology
- Implementation and comparison of different qubit layouts
- Optimization of qubit design for large-scale integration
- Development of a quantum control toolbox suitable for large-scale integrated qubits
- Development of low-temperature peripheral electronics for better qubit control.



Multigate device to design two rows of quantum dots facing each other onto a silicon etched nanowire.
© CEA-Leti

IMPACT

The MOSQUITO project had the tangible effect of bringing quantum physics and electronics industry together in a common goal, which may lead to a revolution in information technology. This also has impact on the educational level. The interdisciplinary character of MOSQUITO brought together students and postdoctoral researchers with either an engineering or physics background and offered them skills that bridge the gap between quantum physics and silicon electronics technology.

Publications

- *«99.992% 28Si CVD-grown epilayer on 300 mm substrates for large scale integration of silicon spin qubits», V. Mazzocchi, P.-G. Sennikov, A.-D. Bulanov, M.-F. Churbanov, B. Bertrand, L. Hutin, J.-P. Barnes, M.-N. Drozdov, J.-M. Hartmann, M. Sanquer, Journal of Crystal Growth, 509, 2019.*
- *«Si MOS technology for spin-based quantum computing», L. Hutin, B. Bertrand, R. Maurand, A. Crippa, M. Urdampilleta, Y.-J. Kim, A. Amisse, H. Bohuslavskyi, L. Bourdet, S. Barraud, X. Jeh, Y.-M. Niquet, M. Sanquer, C. Bäuerle, T. Meunier, S. De Franceschi, M. Vinet, IEEE ESSDERC 2018, Dresden, Germany, Sept. 2018.*
- *«Cryogenic Characterization of 28-nm FD-SOI Ring Oscillators With Energy Efficiency Optimization», H. Bohuslavskyi, S. Barraud, V. Barral, M. Cassé, L. Le Guevel, L. Hutin, B. Bertrand, A. Crippa, X. Jehl, G. Pillonnet, AGM Jansen, F. Arnaud, P. Galy, R. Maurand, S. De Franceschi, M. Sanquer, M. Vinet, IEEE Trans. Elect. Dev., 65, 9, 2018.*
- *«Development of spin quantum bits in SOI CMOS technology», B. Bertrand, L. Hutin, L. Bourdet, A. Corna, B. Jadot, H. Bohuslavskvi, A. Crippa, R. Maurand, S. Barraud, M. Urdampilleta, C. Bäuerle, T. Meunier, M. Sanquer, X. Jehl, S. De Francerschi, Y.-M. Niquet, M. Vinet, IEEE Nano, Cork, Ireland, Jul. 2018.*
- *«All-electrical control of a hybrid electron spin/valley quantum bit in SOI CMOS technology», L. Hutin, L. Bourdet, B. Bertrand, A. Corna, H. Bohuslavskyi, A. Amisse, A. Crippa, R. Maurand, S. Barraud, M. Urdampilleta, C. Bäuerle, T. Meunier, M. Sanquer, X. Jehl, S. De Franceschi, Y.-M. Niquet, M. Vinet, IEEE VLSI Tech. Symp., Honolulu, USA, Jun. 2018.*
- *«Towards quantum computing in Si MOS technology: Single-shot readout of spin states in a FDSOI split-gate device with built-in charge detector», M. Urdampilleta, L. Hutin, B. Jadot, B. Bertrand, H. Bohuslavskyi, R. Maurand, S. Barraud, C. Bäuerle, M. Sanquer, X. Jehl, S. De Franceschi, T. Meunier, M. Vinet, IEEE VLSI Tech. Symp. 2017, Kyoto, Japan, Jun. 2017.*
- *«SOI technology for quantum information processing», S. De Franceschi, L. Hutin, R. Maurand, L. Bourdet, H. Bohuslavskyi, A. Corna, D. Kotekar-Patil, S. Barraud, X. Jehl, Y.-M. Niquet, M. Sanquer, M. Vinet, IEEE IEDM 2016, San Francisco, USA, Dec. 2016.*
- *«Si CMOS platform for quantum information processing», L. Hutin, R. Maurand, D. Kotekar-Patil, A. Corna, H. Bohuslavskyi, X. Jehl, S. Barraud, S. De Franceschi, M. Sanquer, M. Vinet, IEEE VLSI Tech. Symp. 2016, Honolulu, USA, Jun. 2016.*

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Louis Hutin
louis.hutin@cea.fr

Yves Quéré
yves.quere@cea.fr


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My-CUBE

Keywords
3D integration
In-memory-computing
Nanowire
Resistive memory

My-CUBE at a glance

60 months
Mar. 2019 > Mar. 2024

EC Programme
ERC consolidator grant

Project Coordinator
CEA-Leti (FR)

Partners
NA

Total budget
€ 2.7 m.

EC Contribution
€ 2.7 m.

Contract Number
820048

3D integration of a logic/MemorY CUBE for In-Memory-Computing

The MYCUBE project aims to offer, for the first time, a powerful viable technological solution to intensive memory-based computation. It is based on new nano-functionalities created by proximity of silicon nanowire transistors and non-volatile resistive memories integrated in 3D. Research work is cross-disciplinary and ranges from application to technological implementation including circuitry. A typical «In-Memory-Computing» accelerator circuit will be designed and manufactured at CEA-Leti, enhancing energy performance by a factor of 20 compared with a state-of-the-art Von-Neumann circuit.

Objectives

Historical scaling of Complementary-Metal-Oxide-Semiconductor (CMOS) devices is no longer a cornerstone of integrated circuits capable of leveraging the future "data deluge" from the Cloud and cyber-physical systems. At system level, computing performance is now strongly power-limited and the majority of this power budget is used by data transfers between logic and memory circuit blocks in widespread Von-Neumann design architectures. An emerging computing paradigm solution that overcomes this "memory wall" involves processing the information in situ through In-Memory-Computing (IMC).

Today's memory technologies are ineffective for In-Memory-Computing, which will process billions of data items just like the human brain. Things may change with the emergence of three key enabling technologies: non-volatile resistive memory, new energy-efficient nanowire transistors and 3D-monolithic. My-CUBE will leverage these technologies to produce a functionality-enhanced system involving close entangling of logic and memorization. Only this type of technology is capable of supporting the IMC concept's scalability.

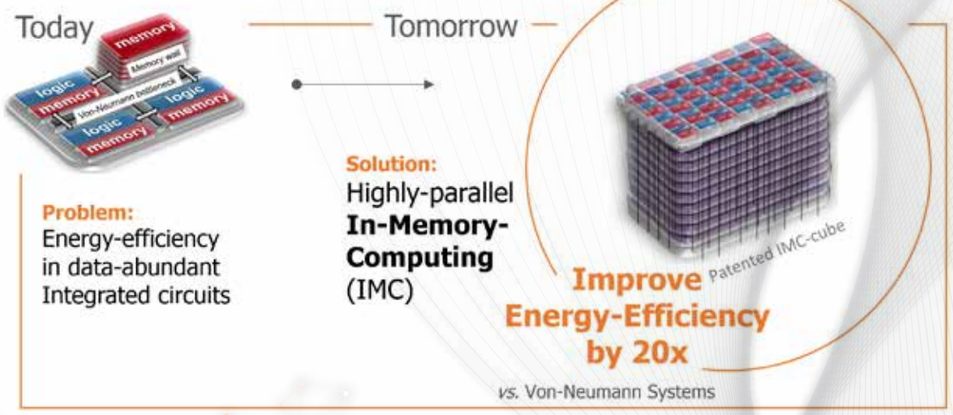
Based on a holistic approach from system to material, My-CUBE's unique solution relies on a new class of nano-technology, combining at fine-grain level the high capacity of non-volatile resistive memory with new junctionless nanowire transistors, 3D-interconnected at low-temperature, to perform data-centric computations. A 3D IMC accelerator circuit will be designed, manufactured and measured. This targets a 20x reduction in (Energy x Delay) Product vs. Von-Neumann systems. This technology, which adds smartness to memory/storage, will not only be a game-changer for artificial intelligence, machine learning, data analytics or any data-abundant computing systems but, more broadly, will also be a key computational kernel for upcoming European low-power, energy-efficient ICs.

CEA-Leti in My-CUBE

The project aims are:

- To demonstrate scalability of In-Memory-Computing and fabricate an IMC-cube
- To develop multi-level 3D-monolithic integration of logic/memory devices at 450°C
- To couple energy-efficient junctionless nanowire and vertically resistive RAM devices
- To design an IMC-cube and exploit its full potential.

Since project launch, CEA-Leti has developed technological modules enabling integration of stacked nanowire transistors coupled with non-volatile memories. Moreover, junctionless transistors have been fabricated and characterized electrically, highlighting their capacity as drivers of oxRAMs. Finally, a bicell layout has been designed with suitably sized transistors. These preliminary results effectively pave the way towards demonstrating functional arrays in 2021 along with circuit design studies in 2020. The thesis of one of our PhD students involves working on a circuit architecture compatible with In-Memory-Computing and leveraging the developed technology.



First topology/technology optimized for IMC at large scale.
© CEA-Leti

IMPACT

MYCUBE takes advantage of Europe's current momentum in technology/circuit innovative solutions. This project proposes differentiating nano-technology to the benefit of the semiconductor industry, fabless circuit design companies and academics. CEA-Leti will ensure design and fabrication as a direct add-on for existing CMOSs to be fully optimized for the new IMC computing paradigm. This technology, which adds smartness to memory/storage, is not only suitable for data-abundant applications but, more broadly, is the kernel of ultimate low-power, energy-efficient integrated circuits in Europe.

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Francois Andrieu
francois.andrieu@cea.fr



NEURAM 3

NeuRAM3

http://www.neuram3.eu/

Keywords
Fully-Depleted Silicon on Insulator
Neural architecture
Resisistive memories
Synapses

NEURAM 3 at a glance

42 months
Jan. 2016 > Jun. 2019

EC Programme
ERC consolidator grant

Project Coordinator
CEA-Leti (FR)

Partners
BE: Imec
CH: IBM Zurich, UZH Switzerland
ES: IMSE
GER: JACU
FR: ST Microelectronics
IT: CNR
NL: Stichting IMEC

Total budget
€ 4.1 m.

EC Contribution
€ 3.2 m.

Contract Number
687299

NEUral computing aRchitectures in Advanced Monolithic 3D-VLSI nano-technologies

The NEURAM 3 project partners have fabricated a mixed-signal analog/digital chip based on neuromorphic architecture that supports state-of-the-art machine learning and spike-based learning mechanisms. In architecture terms, this chip features an ultra-low power, scalable and highly configurable neural architecture that can deliver a gain of a factor 50x in power consumption on selected applications compared to conventional digital solutions. The project also made progress towards developing monolithically integrated 3D technology in Fully-Depleted Silicon on Insulator (FDSOI) based on 28nm design rules with integrated Resistive Random Access Memory (RRAM) synaptic elements.

CEA-Leti in NEURAM 3

• CEA-Leti has presented the first complete integration of a SNN combining analog neurons and RRAM-based synapses. The implemented topology was a perceptron designed to perform hand-written digit classification (MNIST database). Measured classification accuracy was 84% with a 3.6 pJ energy dissipation per spike at synapse and neuron level (up to 5x lower than similar chips using formal coding).

• First demonstration of integration of a full 3D CMOS over CMOS CoolCubeTM with two 1T1R. One 1R was connected to the top transistor and the other to the bottom MOSFET. The top level was integrated with state-of-the-art high-performance FDSOI (Fully-Depleted Silicon On Insulator) process requirements such as High-k/metal gate and raised source and drain.

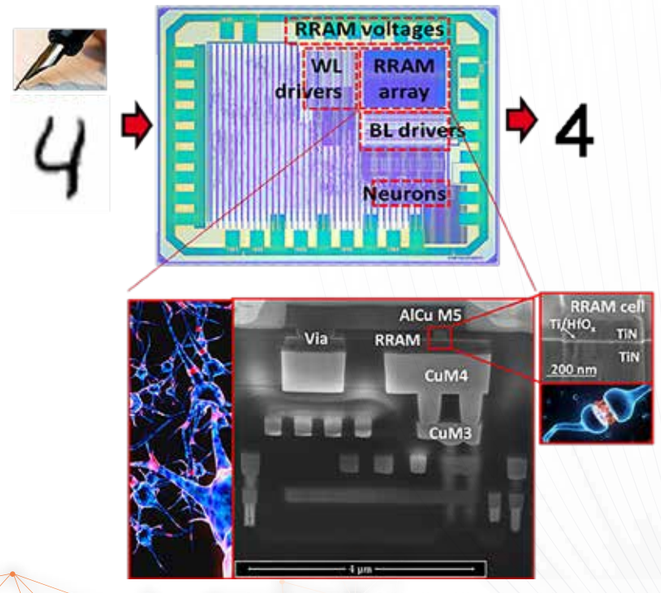
• CEA-Leti has designed and fabricated of a resistive memory-based Content Addressable Memory (CAM) [2]. The proposed CAM cell was largely insensitive to the resistive memory resistance ratio and variability. This circuit allows routing implementation (i.e. sending spikes among neurons) in reconfigurable neuromorphic hardware. This solution offers a smaller area requirement (2 transistors and 2 resistive memories) than conventional solutions (12 transistors) and it is non-volatile (no static power consumption).

Objectives

NeuRAM3 has developed complementary technologies that address the full spectrum of applications from mobile/autonomous objects to high performance computing co-processing, by developing, (1) a technology to implement on-chip learning using native adaptive characteristics of electronic synaptic elements and, (2) a scalable platform to interconnect multiple neuromorphic processor chips for building large neural processing systems.

The neuromorphic computing system has been developed in conjunction with advanced neural algorithms and computational architectures for online adaptation, learning and high-throughput on-line signal processing. This delivers:
- An ultra-low power, massively parallel, non-Von Neumann, computing platform with non-volatile nano-scale devices that support on-line learning mechanisms
- A programming toolbox of algorithms and data structures tailored to the physical architecture's specific constraints and opportunities
- An array of fundamental application demonstrations materializing the basic classes of signal processing tasks.

The neural chip validates the concept and represents an important first step towards developing a European technology platform spanning ultra-low power data processing in autonomous systems (Internet of Things) to energy-efficient large data processing in servers and networks.



Chip micrograph of the Spiking Neural Network circuit for the hand-written digit classification (top) and cross section of the resistive memories integrated between M4 and M5 of a 130nm CMOS technology.
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IMPACT

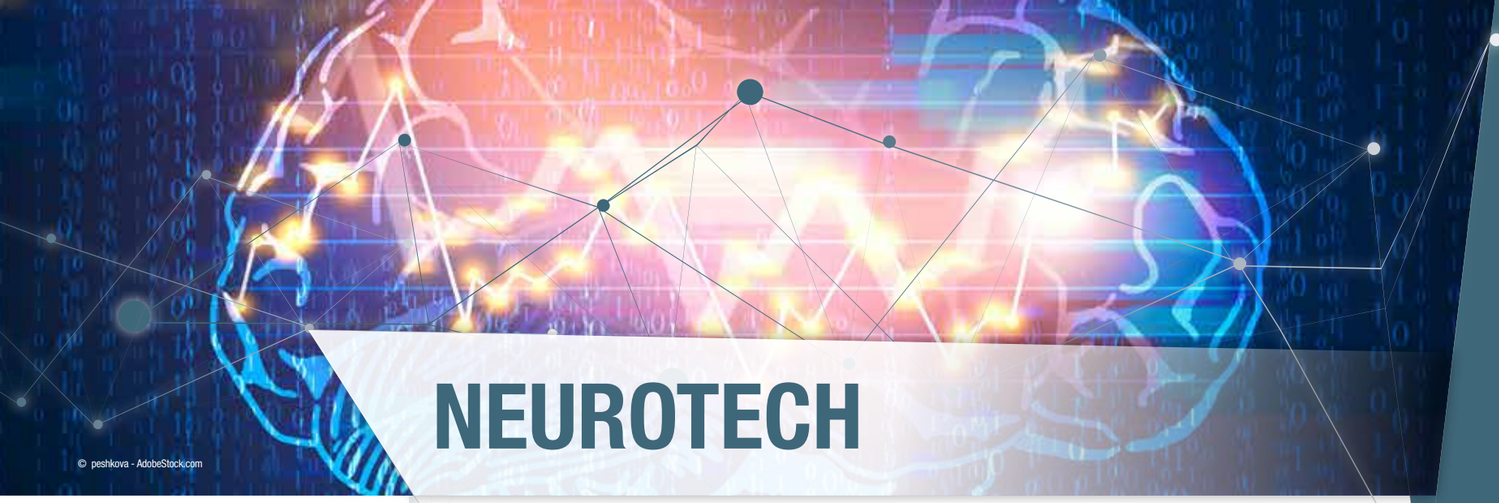
A new EU ICT RIA project (#871371) to advance the NeuRAM3 outcomes has been approved and was started in January 2020. This focuses on memory technologies with multi-scale time constants for neuromorphic architectures (MeM-Scales).

Publications

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[3] A. Valentian et al., IEEE IEDM 2019 Tech. Dig., 10.1109/IEDM19573.2019.8993431. CEA-Leti.
• «An event-based classifier for Dynamic Vision Sensor and synthetic data», E. Stromatias, M. Soto, M.T. Serrano Gotarredona, B. Linares Barranco, Frontiers in Neuroscience, 11 (2017).
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• «A differential memristive synapse circuit for on-line learning in neuromorphic computing systems», M.V. Nair, L.K. Muller, G. Indiveri, Nano Futures 1.3 (2017): 035003.
• «An Ultralow Leakage Synaptic Scaling Homeostatic Plasticity Circuit With Configurable Time Scales up to 100 ks», N. Qiao, C. Bartolozzi, G. Indiveri, IEEE Transactions on Biomedical Circuits and Systems, PP:(99), 2017.
• «Stimulated Ionic Telegraph Noise in Filamentary Memristive Devices», S. Brivio, J. Frascaroli, E. Covi, S. Spiga, Scientific Report 9, 6310 (2019). DOI: 10.1038/s41598-019-41497-3 (Gold Open Access).

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Elisa Vianello
elisa.vianello@cea.fr



NEUROTECH

https://neurotechai.eu/

Keywords
Biologically-inspired computing
Machine Learning
Neuromorphic Computing Technologies

NEUROTECH at a glance

48 months
Jan. 2017 > Dec. 2020

EC Programme
ERC consolidator grant

Project Coordinator
Yulia Sandamirskaya INI UZH (CH)

Partners
BE: Interuniversitair Micro-Electronica Centrum vzw
CH: Research GmbH Switzerland, University of Zurich
DE: Bielefeld University, Heidelberg University
FR: CEA-Leti, University of Bordeaux, Thales
GB: University of Hertfordshire, University of Manchester
IT: Consiglio Nazionale delle Ricerche, Instituto Italiano di Tecnologia Italy

Total budget
€ 0.2 m. + 22 person/months

EC Contribution
€ 0.5 m.

Contract Number
824103

Neuromorphic Technology

The NEUROTECH project is assembling and curating a coherent collection of educational resources relating to all aspects of Neuromorphic Computing Technologies (NCTs) with the aim of sharing core educational events to disseminate curricula to other communities and to promote NCT among decision makers.

Objectives

Neuromorphic engineering is a ground-breaking approach to designing computing technology that draws inspiration from powerful, efficient biological neural processing systems. Neuromorphic devices are able to carry out sensing, processing and motor control strategies based on ultra-low power performance. Today's neuromorphic community in Europe is leading the state of the art in this domain. It boasts ever more laboratories working on the theory, modelling and implementation of neuromorphic computing systems implementing conventional VLSI technologies, emerging memristive devices, photonics, spin-based and other nano-technological solutions. Robust, sustainable communication between research laboratories and stakeholders is required to ensure technological uptake and meet the needs of real world applications in future task solving products in industry, healthcare, assistive systems and consumer devices. NEUROTECH focuses on, (1) creating a comprehensive online platform integrating data on all parties involved, reflecting the state of the art and showcasing latest technological progress to strengthen the NCT community and enhance its impact and visibility, (2) actively reaching out to industrial stakeholders to secure their involvement in shaping future research and to facilitate uptake of existing technology, (3) promoting public interest in NCT by showcasing key technologies and, (4) designing educational resources in this interdisciplinary field to target students of different backgrounds. Coordination and Support Action (CSA) will be the link to consolidation and dissemination of state-of-the-art neuromorphic technology, to creating a roadmap for future progress to unleash the power of NCT in future smart technologies.

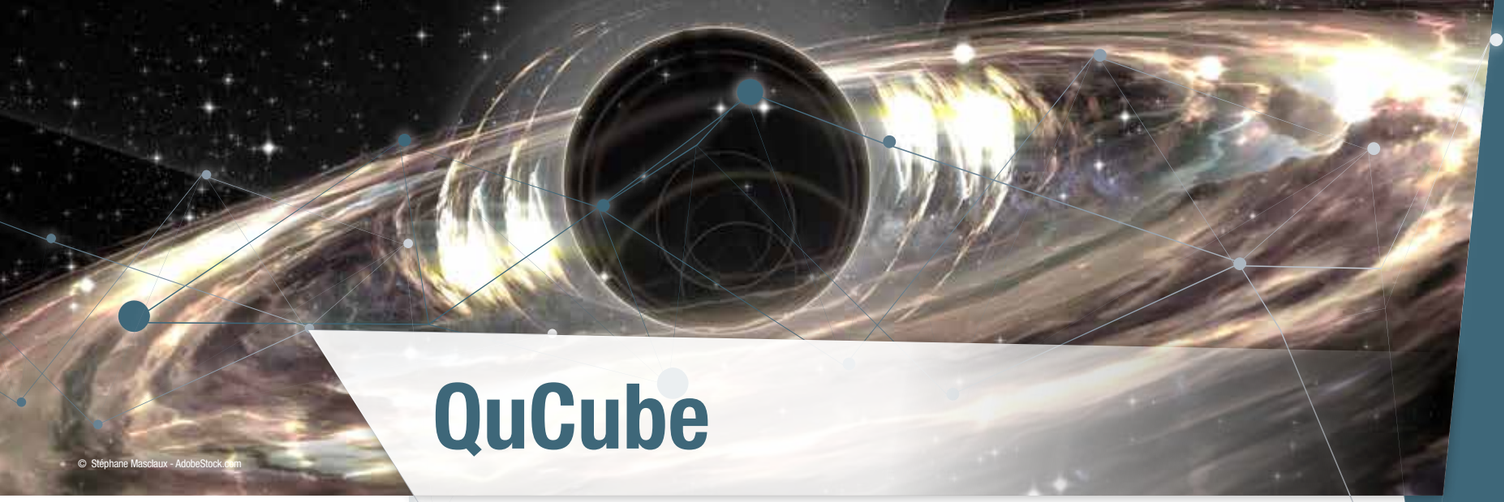
CEA-Leti in NEUROTECH

CEA-Leti is contributing to workshops and on-line meetings aimed at drafting statements on ethical issues and the threats of Artificial Intelligence (AI) enabled by NCA.



Elisa Vianello
elisa.vianello@cea.fr

Carlo Reita
carlo.reita@cea.fr



QuCube

Silicon based quantum accelerator

QuCube project leaders from CEA-Leti, INAC and Néel fundamental research institutes are deploying their teams' strengths to build a quantum processor, which integrates at least a hundred quantum bits (qubit), thereby demonstrating a first functional logic qubit; a truly decisive step towards a future quantum computer.

Keywords
Computing
Physics
Quantum computing
Technology

QuCube at a glance

72 months
Feb. 2019 > Feb. 2025

EC Programme
ERC synergy

Project Coordinator
CEA-IRIG (FR), Institut Néel CNRS (FR), CEA-Leti (FR)

Partners
DE: German Aerospace Center, Ibeo Automotive Systems, IT21, Objective Software, Robert Bosch, Zigpos
FR: BeSpoon, CEA-Leti, Eurecom
LU: FBConsulting
NL: PaulsConsultancy, Tass International
SE: Chalmers University of Technology Gothenburg

Total budget
€ 14 m.

EC Contribution
€ 14 m.

Contract Number
810504

CEA-Leti in QuCube

On a technical level, the QuCube project is original and a cornerstone in several ways. CEA-Leti is providing its unique know-how in 3D integration processes, including smart-cut and wafer-bonding methods [Fou00], semiconductor epitaxy[Wid14], ground-breaking Cool-Cube™ and high density technologies [Vin16, Viv17] for vertical integration of functional devices (e.g. transistors and memories) with unprecedented alignment accuracy (<5nm). The QuCube project will use 300-mm SOI wafers with an isotopically purified 28Si device layer, currently being grown at CEA-Leti. In addition, CEA-Leti's and CEA-Inac's extensive skills in device modeling and simulation [Niq16] (Y.-M. Niquet's teams) are ensuring highly valuable guidance in designing and optimizing qubit devices.

CEA-Leti and its partners have demonstrated 99% fidelity in spin read-out [urd19] in 2019. Our teams have ensure the migration of the qubit technology to immersion lithography with a 20 nm critical dimension and a 80nm pitch, and have fabricated 28Si qubit test structures for low temperature characterization. A Trans Impedance Amplifier (TIA) has been designed [leg19] to increase throughput under these conditions. This relies on low a compact low temperature FDSOI model calibrated using an accurate low temperature technology characterization [paz19].

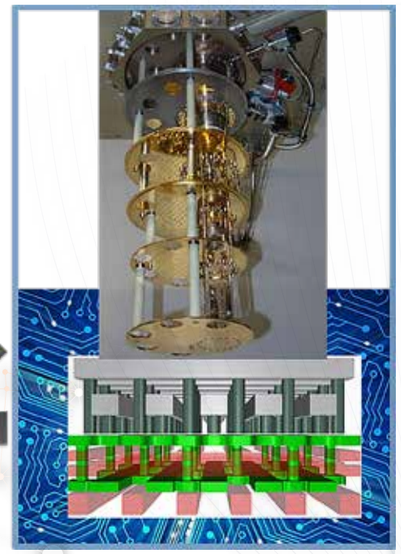
[urd19] M Urdampilleta et al, Gate-Based High Fidelity Spin Read-out in a CMOS Device, https://arxiv.org/abs/1809.04584
[leg19] L Le Guevel et al, submitted at IEDM19
[paz19] B Paz et al, submitted at IEDM19

Objectives

Originally conceived to describe the microscopic world of atoms and elementary particles, theoretical quantum mechanics was eventually used to predict macroscopic phenomena, e.g. semiconductor electrical and optical properties, resulting a wide range of technological applications that have changed our lifestyle. However, foundational properties such as quantum superposition and entanglement have remained essentially unexploited. Their use may allow us to achieve computation powers that are inaccessible to conventional digital computers, thereby offering unprecedented opportunities.

In a quantum computer, the elementary data bits are encoded on two-level quantum systems called qubits. Since qubits interact with the uncontrolled degrees of freedom of their environment, changes in their quantum states can quickly become unpredictable, leading to reduced qubit fidelity. In topological quantum computing schemes, e.g. the surface code, lower fidelity is compensated by using decoherence-free logical qubits composed of a many (~103) entangled physical qubits. An effective quantum processor should therefore accommodate millions of qubits, at least. Although dauntingly large, this number is still small compared to the number of transistors in modern silicon microprocessors.

QuCube is leveraging industrial-level silicon technology to build a quantum processor containing hundreds of spin qubits confined to a two-dimensional array of electrostatically defined silicon quantum dots. To overcome the challenge of addressing the qubits individually, we hnave adopted a 3-dimensional architecture designed to accommodate, on separate planes, the charge sensing devices required for qubit readout and the metal gate lines for electrical control and measurement. The gate lines are operated on a multiplexing basis to provide a scalable wiring layout. Fault-tolerant logical qubits and quantum simulations of complex Hamiltonians will be implemented.



Quantum accelerator
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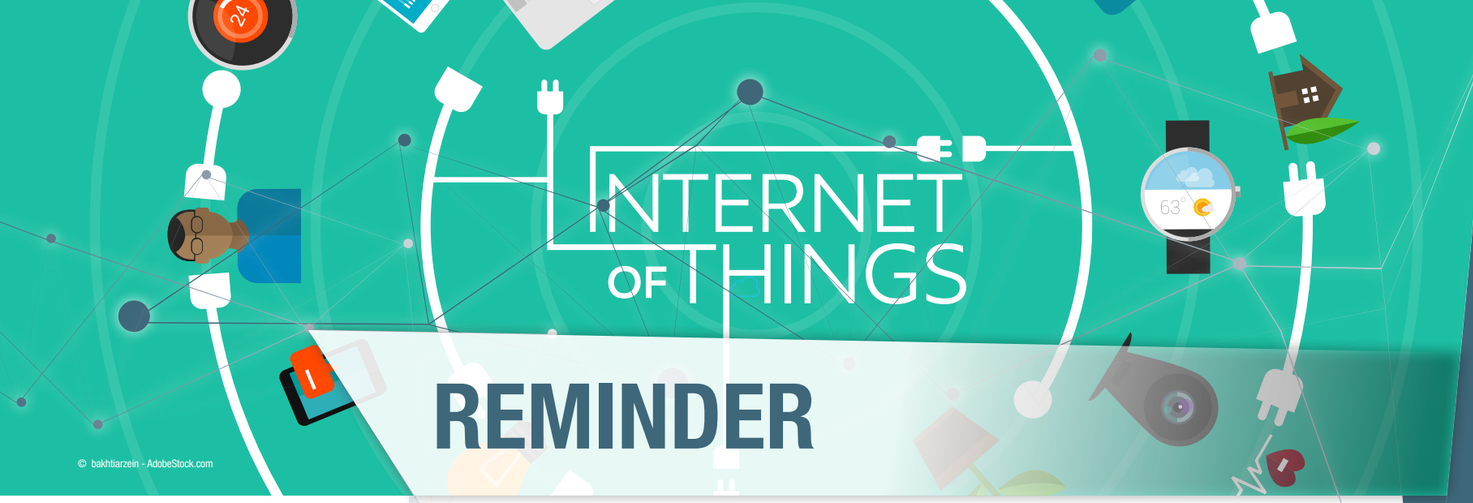
Through its fabrication and operation of quantum processors integrating at least a hundred qubits, the aim of the QuCube project is to **break ground towards large scale qubit integration**. When available, the targeted quantum processors will provide a sizable **test bench for testing and optimizing system-specific quantum correction algorithms** and for **evaluating the best upscaling strategy**. In principle, the proposed qubit architecture is designed to be scalable up to millions of qubits, but **alternative scaling routes may be investigated based on the outcome of this project** (e.g. architectures based on fairly small qubit arrays operating as logical qubits, well separated from each other and connected by long range quantum buses; these have not been produced but may soon become available). We are not aware of any alternative qubit platform offering large scale qubit integration (millions of qubits would seem necessary for a useful fault-tolerant quantum processor). In this sense, the QuCube project has a clearly high-risk/high-gain profile. The know-how and IP generated by QuCube could contribute to the development of a European spin-off company ensuring industrialization and subsequent commercialization.

Publications
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- *«Efficient controlled-phase gate for single-spin qubits in quantum dots», T. Meunier, V. Calado, and L. Vandersypen, Phys. Rev. B 83, 121403(R) (2011).*
- *«Opportunities brought by sequential 3D CoolCube™ integration», M. Vinet, P. Batude, C. Fenouillet-Beranger, L. Brunet, V. Mazzochi, C.-M.V. Lu, F. Deprat, J. Micout, B. Previtali, P. Besombes, and others, in Solid-State Device Res. Cont. (ESSDERC), 2016 46th Eur. (2016), pp. 226–229.*

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Maud Vinet
maud.vinet@cea.fr

Yves Quéré
yves.quere@cea.fr



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REMINDER

Revolutionary embedded memory for internet of things devices and energy reduction

The aim of the REMINDER project is to develop an innovative embedded DRAM solution by removing the capacitor, which normally stores information in a standard DRAM structure. This is called a 1T-DRAM. It uses a device built on SOI substrate to enlarge the FDSOI platform offer. Following development of electrical characterization, simulation, compact modeling and design enablement tools, the ultimate objective is to manufacture a functional memory matrix of some Mbits.

www.reminder2020.eu

Keywords
Internet of Things (IoT)
Memory
Ultra low power

REMINDER at a glance

48 months
Jan. 2017 > Dec. 2020

EC Programme
H2020-ICT-25-2015

Project Coordinator
CEA-Leti (FR)

Partners
DE: German Aerospace Center, Ibeo Automotive Systems, IT21, Objective Software, Robert Bosch, Zigpos
FR: BeSpoon, CEA-Leti, Eurecom
LU: FBConsulting
NL: PaulsConsultancy, Tass International
SE: Chalmers University of Technology Gothenburg

Total budget
€ 4.5 m.

EC Contribution
€ 3.6 m.

Contract Number
687931

Objectives

REMINDER develops an embedded DRAM solution optimized for ultra-low-power consumption and variability immunity, specifically focused on Internet of Things cutting-edge devices. The objectives of REMINDER are:
• investigation (concept, design, characterization, simulation, modelling), selection and optimization of a Floating-Body memory bit cell in terms of low power and low voltage, high reliability, robustness (variability), speed, reduced footprint and cost;
• design and fabrication in FDSOI 28nm (FD28) and FDSOI 14nm (FD14) technology nodes of a memory matrix based on the optimized bit-cells developed. Matrix memory subcircuits, blocks and architectures are carefully analysed from the power-consumption point of view.
In addition, variability tolerant design techniques underpinned by variability analysis and statistical simulation technology are widely considered;
• demonstration of a system on chip application using the developed memory solution and benchmarking with alternative embedded memory blocks.
The eventual replacement of Si by strained Si/SiGe and III-V materials in future CMOS circuits would also require the redesign of different applications, including memory cells, and therefore we also propose the evaluation of the optimized bit cells developed in FD28 and FD14 technology nodes using these alternative materials.
The fulfilment of the objectives above also implies the development of:
• new techniques for the electrical characterization of ultimate CMOS nanometric devices. This allows us to improve the CMOS technology by boosting device performance;
• new behavioural models, incorporating variability effects, to reach a deep understanding of nanoelectronics devices;
• advanced simulation tools for nanoelectronic devices for state of the art, and emerging devices;
• extreme low power solutions.
The consortium supporting this project is ideally balanced with 2 industrial partners, 2 SMEs, 2 research centers and 3 universities.

CEA-Leti in REMINDER

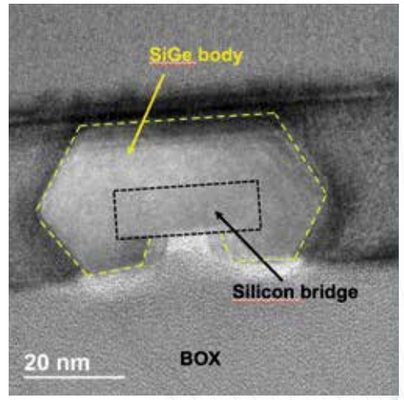
• Technology
> An A2RAM cell comprising an SOI transistor with a silicon film (approx. 25nm) thicker than CMOS applications. The film is divided into a top section used used to store information and a bottom section is used to read information. The bottom section is a buried doped layer (a bridge) that short-circuits the source and drain.
> Objective:
• Demonstrate that a nanowire structure can improve A2RAM performance and scaling
• Demonstrate that a heterostructure between the storage region (SiGe material) and the bridge (Si material) can improve A2RAM performance.
> Process flow definition of A2RAM devices using CEA-Leti nanowire exploiting Coolcube technological developments to build the bridge:
• A2RAM structure definition by finite element simulation (TCAD): determining target film thicknesses, bridge doping and thickness, gate length and Ge quantity in the SiGe storage region
• S/D implanting and annealing steps defined by TCAD
• Bridge implanting and annealing steps defined by TCAD.
> Successful fabrication of nanowire-based A2RAM in a CEA-Leti clean room.

• Electrical characterization
> Experimental demonstration of nanowire-based functionality of A2RAM devices:
• Demonstrating bridge presence using capacitive measurements
• Demonstrating memory effect: '1' and '0' states can be programmed and read.

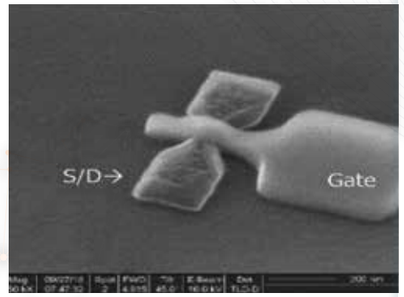
• Simulation
> TCAD environment developed for Z2FET device simulation and shared with REMINDER partners:
• Z2FET device is a partially gated PIN diode on SOI usually dedicated to ESD applications but used here as a 1T-DRAM structure.
> In-depth knowledge of Z2FET device, especially DC hysteresis, through extensive TCAD simulations, forming the basis of Z2FET compact model development
> TCAD simulation to calibrate the Z2FET compact model
> TCAD supporting technological development involving
nanowire-based A2RAM fabrication.

• Modelling
> Compact model development of Z2FET for project final demonstrator
design: 1T-DRAM matrix using Z2FET devices.
> Z2FET compact model includes:
> DC behavior with hysteresis
> Memory operation (write, erase and read)

•Other
> Workshop organization for 1T DRAM solutions at EuroSOI-ULIS 2019 conference in Grenoble.



TEM cross section after SiliconGermanium body epitaxy showing the evidence of body-bridge stack into A2RAM devices.
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SEM view after S/D epitaxy showing gate and source/drain (S/D) regions of A2RAM devices.
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IMPACT

When functional, the 1T DRAM matrix demonstrator will be a first demonstration of a 1T DRAM matrix on SOI. Close cooperation has been set up between partners Granada University, Glasgow University and Grenoble's IMEP-LAHC laboratory, especially for TCAD simulation and electrical characterization.

Publications

• *«Z²-FET DC hysteresis: deep understanding and preliminary model», J. Lacord et al., SISPAD 2017.*
• *«Optimization guidelines of A2RAM cell performance through TCAD simulations», F. Tcheme-Wakam et al., SISPAD 2017.*
• *«Z²-FET SPICE Model: DC and Memory Operation», S. Martinie et al., S3S 2017.*
• *«MSDRAM, A2RAM and Z²-FET performance benchmark for 1T-DRAM applications», J. Lacord et al., SISPAD 2018.*
• *«Evidence of fast and low-voltage A2RAM '1' state programming», F. Tcheme Wakam, SISPAD 2018.*
• *«Doping profile extraction in thin SOI films: Application to A2RAM», F. Tcheme Wakam, EUROSOI 2018.*
• *«A comprehensive model on field-effect pnpn devices (Z²-FET)», Y. Taur, SSE 2017.*
• *«Ultra-low power 1T-DRAM in FDSOI technology», H. El Dirani et al., microelectronic engineering journal 2017.*
• *«Ultra-low power 1T-DRAM in FDSOI technology», M.-S. Parihar et al., ESSDERC 2017.*
• *«Impact of carrier lifetime on Z²-FET operation», M.-S. Parihar et al., EUROSOI 2017.*
• *«The mystery of the Z²-FET 1T-DRAM memory", M. Bawedin et al., EUROSOI 2017.*
• *«Z²-FET as Capacitor-Less eDRAM Cell For High-Density Integration», C. Navarro et al., ED 2017.*
• *«Extended Analysis of the Z²-FET: Operation as Capacitorless eDRAM», C. Navarro et al., TED 2017.*
• *«A review of the Z²-FET 1T-DRAM memory: operation mechanisms and key parameters», S. Cristoloveanu, SSE 2017.*
• *«Insight into carrier lifetime impact on band-modulation devices», M.-S. Parihar, SSE 2017.*
• *«Low-Power Z²-FET Capacitorless 1T-DRAM», M.-S. Parihar, IMW 2017.*
• *«Z²-FET memory matrix in 28 nm FDSOI technology», M.-S. Parihar, EUROSOI 2018.*

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Joris Lacord
Joris.lacord@cea.fr

Yves Quéré
yves.quere@cea.fr



SIPOB-3D

Co-Design for System-in-Package-on-Board: Managing Complexity and Diversity to Create Novel 3D Compact Systems

The SIPOB 3D project is addressing 3D high-density technologies and System-in-Package (SiP) technologies for compact system integration, which is needed for smart city applications. The aim of SIPOB 3D is to develop the next level of design methodology for 3D integrated systems, including not only chip and package, but also board domain.

Keywords
3D
Co-design
System-in-Package
TSV

SIPOB-3D at a glance

39 months
Mar.2016 > May 2019

EC Programme
CATRENE

Project Coordinator
Infineon Technologies (DE)

Partners
DE: Computer Simulation Technology AG, Continental Automotive, FAU Erlangen-Nuremberg, Fraunhofer EAS/IIS & IZM ASSID, Hitex Tools Development GmbH, Hofmann Leiterplatten, Infineon Technologies, Schöller Electronics, Symeo GmbH
FR: CEA-Leti, STMicroelectronics Crolles and Grenoble, Université de Savoie IMEP-LAHC

Total budget
82 Person x year

EC Contribution
0.7 m.

Contract Number
776886

CEA-Leti in SIPOB-3D

CEA-Leti's goal in the SIPOB 3D project is to develop and promote a system level design methodology to explore, define and design 3D circuits. Moore's Law effectively limits further scaling of many systems at reduced cost. Today's 3D technology allows integration of different die layers to build a multi-layer stacked circuit. 3D technology offers the possibility of designing heterogeneous circuits using different core technologies (logic, analog, memories, MEMs, etc.) and to offer a full scope of new architectures. Various challenges are raised, such as system performance estimation, power delivery and thermal dissipation due to potentially higher power density. 3D technology offers a wide variety of options (Die2Wafer, Wafer2Wafer, TSVmiddle, µ-bumps, Face-2Face, Face2Back, etc.), which open the door to a broad range of potential architectures. System design is becoming increasingly complex, prompting definition of co-design methodology using appropriate CAD tools.

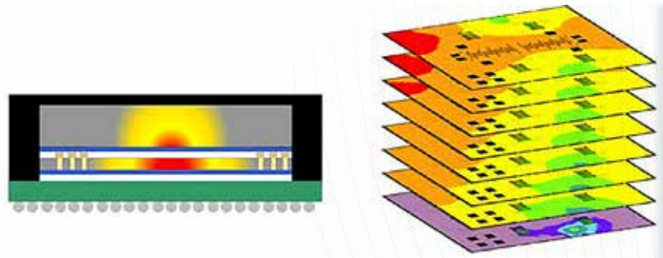
In this context, CEA-Leti is contributing on the following tasks:

- Development of 3D performance assessment models by taking into account 3D technology parameters and design parameters such as system communication protocols. The final goal is to assist system partitioning based on early system performance assessments
- Evaluation and optimization of 3D system thermal effects based on the whole system from accurate fine grain objects (TSVs) to multiple layers, package and full board aspects (Fan, Thermal Sink, etc.). The aim is to study thermal effects within a 3D system and to optimize various parameters: design-related (floorplan estimation, power location), technology-related (materials) and system-related (packaging options, heat sink)
- Development of a co-design methodology based on existing CAD tools and formats, which will enable joint investigation and optimization of the 3D circuit, its package and final board. Compared to previous design methodology, in which each object was separately defined, co-design allows us to investigate together the increasing options and high-level complexity of 3D systems (hundreds of thousands of micro-bumps)
- Ensuring a development method for 3D power delivery network design and estimation. In 3D technology, the complex power delivery network (power and ground) must be investigated, estimated and designed
- Provision of a system level representative demonstration as an architecture test-case to set up, apply and validate newly developed design methodologies. The proposed test-case represents a massive 3D chiplet-based system providing a multi-core for High Performance Computing (HPC) applications.

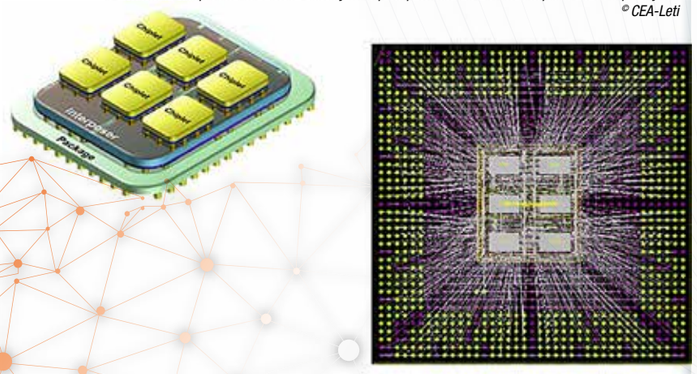
In achieving these objectives, CEA-Leti is cooperating with STMicrolectronics, various Fraunhofer Institutes and Mentor Graphics.

Objectives

More-than-Moore (MtM) technologies, 3D high-density technologies and SiP technologies are prerequisites for compact system integration, which is needed for smart city applications.
The project consortium is investigating a methodology for mapping the best technology available in companies with the aim of designing the optimum SIPOB 3D device faster, better and cheaper; expensive "trial and error" loops must be avoided. The physics behind the technologies and materials of a compact SIPOB 3D device must be understood, when designing a compact system, hence emphasis must be placed on hardware assessment implementing advanced technologies. SIPOB 3D is a holistic approach, which includes investigation and simulation of the models included in a design library; the design methodology considers multi-physics and the capabilities involved in setting up an optimum system as a whole. Data transfer between different domains needs to be investigated and optimized, especially among board suppliers and packaged chip suppliers. A global optimum, on-chip package and on-board level need to be achieved. SIPOB 3D is projected to exploit the CoSiP backbone to enable chip/package and board (PCB) co-design for footprints and connectivity. New SiP design rules and checks are essential and are being integrated into the design environment.
A world-leading consortium has been formed: European semiconductor suppliers Infineon Technologies and STMicroelectronics, both major producers in Europe, are cooperating with Continental and Symeo, companies working on subsystem on-board development, EDA vendor CST and the three small companies (Hofmann LP, Schöller-Electronics and Hitex); these three are providing input on the PCB interface. The above corporate partners are supported by four leading European research institutes.
The SIPOB 3D project outcomes are shorter time to market and support to Europe in managing the complexity and diversity involved in establishing compact 3D integral systems including chip, package and board.



3D Thermal Dissipation and Power Delivery IRdrop map within a 3D stack composed of multiple layers.
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3D Chiplet based partitionning: co-design of chiplet + interposer + package, full view using XSI tools.
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IMPACT

The SIPOB 3D project has enabled CEA-Leti to develop an advanced design methodology, mostly with respect to thermal simulation and 3D circuit-package co-design. This work has been performed in active cooperation with Mentor Graphics. Unlike other SIPOB3D project partners, which have promoted 3D technology at packaging level (SiP), CEA-Leti is promoting and developing 3D at circuit level for further system integration with an HPC context. The 3D design methodologies developed show that Europe can be fully autonomous in terms of 3D design and that this knowledge can be applied to designing future European 3D circuits such as those addressed by the European Processor Initiative (EPI) H2020 program.

Publications

- *"Dielet Processing", P. Vivet, Special Session, 3DIC'2016 Conference, San Francisco, USA, Nov 2016.*
- *« Chiplet Partitioning for 3D Manycore Architectures », D. Dutoit, 3DASIP'2016, San Francisco, USA, Dec 2016.*
- *"Multi-Scale Thermal Modeling Methodology: Application and Exploration of 3D Architectures", P. Vivet, User2User Mentor Graphics Forum, April'2017, Santa Clara, USA.*
- *"Chiplet-based partitioning using Smart Interposer for High Performance Computing 3D Integrated Systems", P. Vivet, 3D Summit, Invited Talk, Dresden, Germany, January 2019.*

TRL
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Pascal Vivet
pascal.vivet@cea.fr

Denis Dutoit
denis.dutoit@cea.fr



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SUPERAID7

SUPERAID 7

www.superaid7.eu

Keywords
Advanced CMOS
Simulation
Technology

SUPERAID7 at a glance

36 months
Jan. 2016 > Dec. 2018

EC Programme
H2020-ICT-25-2015

Project Coordinator
Fraunhofer IISB (DE)

Partners
AT: TU Wien
FR: CEA-Leti
UK: Gold Standard Simulans (Synopsis), University of Glasgow

Total budget
€ 3.4 m.

EC Contribution
€ 3.4 m.

Contract Number
688101

Objectives

Process variability is ever more critical among the physical limitations that curb progress in nanoelectronics for aggressively scaled More-than-Moore systems. The effects of different sources of process variation, both systematic and stochastic, influence each other and lead to variations in the electrical, thermal and mechanical behavior of devices, interconnects and circuits. Correlations are of prime importance because they drastically affect the percentage of products that meet specifications. Although comprehensive experimental investigation of these effects is largely impossible, modelling and simulation (TCAD) offers the unique possibility of predefining process variations and tracing their effects on subsequent process steps and on manufactured devices and circuits simply by changing the relevant input data. This major requirement for and capability of simulation are, among other needs, highlighted in the International Technology Roadmap for Semiconductors (ITRS).

SUPERAID7 builds upon the successful FP7 SUPERTHEME project, which focused on advanced More-than-Moore devices. It is aimed at establishing a software system for simulating the impact of systematic and statistical process variations on advanced More-than-Moore devices, circuits and especially interconnects down to the 7 nm node and below. This requires better physical models and extended compact models. Device architectures addressed in the benchmarks include TriGate/ΩGate FETs and stacked nanowires including alternative channel materials. The software developed can be benchmarked using CEA-Leti background and sideground experiments. Main areas of usage include software commercialization through partner Synopsis and support for device architecture activitities at CEA-Leti.

Stability Under Process Variability for Advanced Interconnects and Devices Beyond 7 nm node

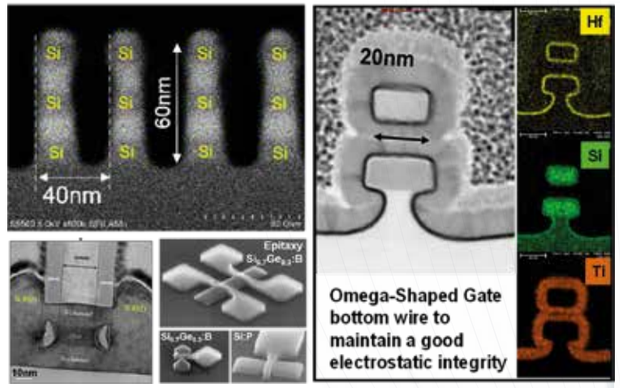
In the SUPERAID7 project, the variability induced by different sources of process variation has been investigated in relation to the performance of Gate-All-Around Stacked-Nanosheet MOSFET. After fabricating devices, the CEA-Leti-NSP model was developed, validated and calibrated using experimental data. Subsequently, the extracted variability-aware compact models demonstrated how different process parameters can affect different aspects of circuit behavior, which is a key issue for future advanced CMOS technology nodes.

CEA-Leti in SUPERAID7

CEA-Leti first described and summarized a very detailed database of morphological/electrical results from Trigate nanowire devices, including a wide range of NW widths (8 nm £ W £ 10 µm), NW heights (6 nm £ Hfin £ 24 µm) and transport orientations (along [110] and [100] direction). Electron and hole transport was described for both unstrained and (tensile/compressive) strained Si and SiGe channels.

CEA-Leti then designed and specified the Gate-All-Around (GAA) stacked nanowire devices including inner spacers and SiGe source-drain (S/D) stressors. The Precession Electron Diffraction (PED) method was applied for the first time at nm-scale accuracy. It was used to quantify deformation and provide useful information on strain fields at different fabrication stages. Two major challenges facing development of stacked wire technology were addressed, specifically inner spacers and strain engineering in 3D integration processes.

Finally, a comprehensive study ranging from integration of 3D Gate-All-Around stacked nanowire MOSFET devices to SPICE modeling was conducted. Devices were successfully fabricated on SOI substrates using a replacement high-K metal gate process and self-aligned contacts. Back-biasing was efficiently used to highlight a drastically improved electrostatics in the upper GAA Si channels. Advanced electrical characterization of these devices enabled CEA-Leti to calibrate a new version of the physical compact model (CEA-Leti-NSP) to assess the performance of GAA FET ring oscillators.



TEM images showing a Fin pitch of 40nm, inner spacer integration and vertically stacked wires field effect transistors.
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IMPACT

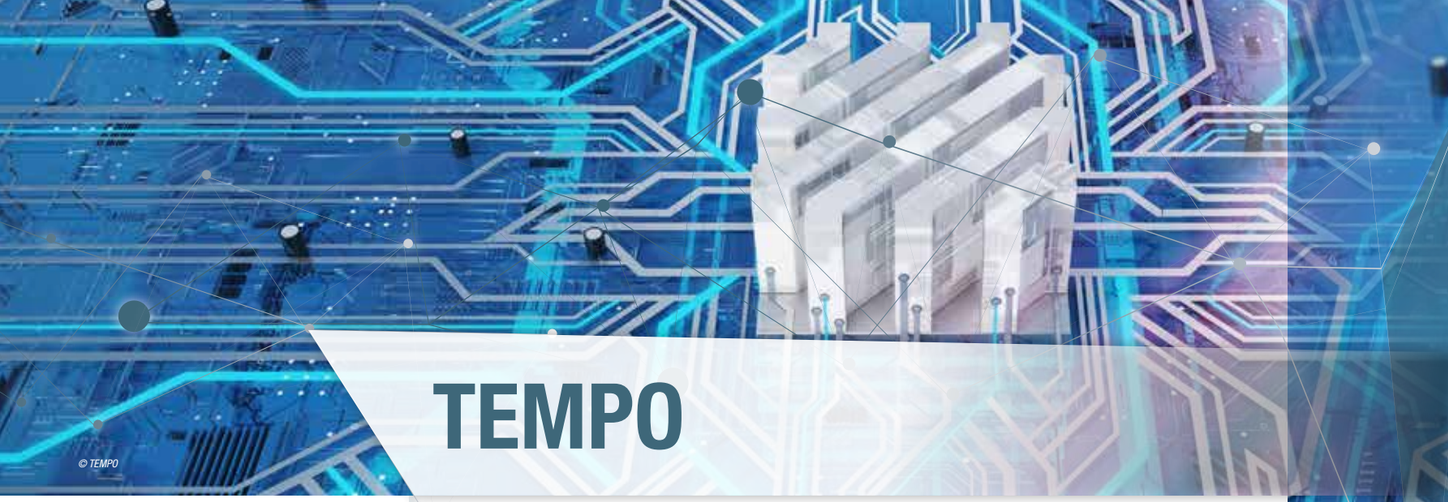
The project has been implemented, kept up-to-date and in use for internal and public information since March 2016. To date, 40 research papers have been published on the strength of the SUPERAID7 project: half of them as Gold Open Access and the remainder as Green Open Access. SUPERAID7 has been strongly represented, especially at SISPAD, IEDM and other conferences. In addition to two co-organized workshops associated with SISPAD 2016, the SUPERAID7 reporting period workshop foreseen in the Description of Action was organized in association with ESSDERC / ESSCIRC 2018. Finally, the CEA-Leti-NSP model has been proposed and discussions are ongoing for international standardization via the Compact Model Coalition.

Publications

- *«Electrical characterization of vertically stacked p-FET SOI nanowires», B. Cardoso Paz, M. Cassé, S. Barraud, G. Reimbold, M. Vinet, O. Faynot, M. Pavanello, Solid-State Electronics, 141, 84, 2018.*
- *«Methodology to separate channel conductions of two level vertically stacked SOI nanowire MOSFETs», B. Cardoso Paz, M. Cassé, S. Barraud, G. Reimbold, M. Vinet, O. Faynot, M. Pavanello, Solid-State Electronics, 149, 62, 2018.*
- *«Top-down fabrication and electrical characterization of Si and SiGe nanowires for advanced CMOS technologies», S. Barraud, B. Previtali, V. Lapras, R. Coquand, C. Vizioz, J.-M. Hartmann, M. Cassé, Submitted to Semiconductor Science and Technology.*
- *«New method for individual electrical characterization of stacked SOI nanowire MOSFETs», B. Cardoso Paz, M. Cassé, S. Barraud, G. Reimbold, M. Vinet, O. Faynot, M. Pavanello, IEEE SOI-3D-Subthreshold Microelectronics Technology Unified Conference (S3S), 2017: DOI: 10.1109/S3S.2017.8309237.*
- *«Performance and transport analysis of vertically stacked p-FET SOI nanowires», B. Cardoso Paz, M. Pavanello, M. Cassé, S. Barraud, G. Reimbold, M. Vinet, O. Faynot, EUROSOI-ULIS Workshop, 2017, DOI: 10.1109/ULIS.2017.7962606.*
- *«An improved mobility model for FDSOI TriGate and other Multi-Gate Nanowire MOSFETs down to nm-scale dimensions», M. Cassé, J. Pelloux-Prayer, Z. Zeng, Y.-M Niquet, F. Triozon, S. Barraud, G. Reimbold, IEEE SOI-3D-Subthreshold Microelectronics Technology Unified Conference (S3S), 2017: DOI: 10.1109/S3S.2017.8309241.*
- *«Stacked-Nanowires/Nanosheets GAA MOSFETs – From technology to design enablement «– Oral invited, S. Barraud & al., SSDM conference, Sendai, Japan, 2017.*
- *«Performance and design considerations for Gate-All-Around Stacked-Nanowires FETs» – Oral invited, S. Barraud & al., IEDM conference, San-Francisco, US, 2017.*
- *«Tunability of parasitic channel in GAA stacked nanosheets», S. Barraud & al., IEDM conference, San-Francisco, US, 2018.*

TRL
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Sylvain Barraud
sylvain.barraud@cea.fr



TEMPO

Technology and hardware for nEuromorphic coMPuting

When deploying Artificial Intelligence (AI), specific hardware solutions capable of assimilating multiple data from different sensors (radar, lidar, camera) must be developed within the specified constraints of reduced time, low latency, low power consumption and high resolution. The aims of the TEMPO project were to design and combine performing transistors and new emerging memories to build novel neural networks capable of analysing complex situations such as object detection in real time (automotive, space, health and multiple applications).

Keywords
Artificial intelligence
Design
Edge computing
Hardware
Memories

TEMPO at a glance

36 months
May 2019 > Apr. 2022

EC Programme
ECSEL 2018

Project Coordinator
Imec (BE)

Partners
CH: aiCortex, University of Zurich
DE: Bosch, Fraunhofer, Infineon, Innosent, University of Dresden, Valeo, Videantis
FR: ST Microelectronics, Thales Alenia Space, Valeo
NL: Atogear, Imec-NL, Philips Health, Philips Research

Total budget
€ 33 m.

EC Contribution
€ 10,5 m.

Contract Number
Grant Agreement No. 826655

CEA-Leti in TEMPO

During the TEMPO project, **CEA institutes Leti and List contributed right from novel design to hardware implementation, in CEA-Leti's 300mm cleanroom dedicated to Spiking Neural Network (SNN) applications,** mainly in support of a VALEO ambitious user case implementing a LIDAR sensor. CEA-Leti designed new "neuromorphic" structures to evaluate 1T-1R (one transistor – one resistive element) on top of advanced CMOS logic; their production, based on 28 nm FDSOI technology, being supported by ST Microelectronics (Crolles, France). Following development and implementation of the specific memory module in the CEA-Leti 300mm cleanroom, we finalised the interconnections to allow testing, part of which was supported by CEA-List (Saclay, near Paris) using so-called "N2D2" hardware. The TEMPO project enabled benchmarking of different memories, so CEA-Leti can now evaluate PCRAM and OxRAM resistive memories for a suitable design targeting SNN applications.



Objectives

The TEMPO project brought together the three premier European RTOs, industrial fabrication facilities and leading application partners in the field of neuromorphic computing, which is subject to intense global competition in view of upcoming intelligent machines. The underlying concrete aims of the TEMPO project were to:

- Enable joint development of participating European RTOs, foundries and leading application development companies in identifying emerging semiconductor technologies that best fit neuromorphic hardware and address relevant applications
- Evaluate current concepts for implementing neuromorphic hardware based on Key Performance Indicators (KPIs) at device, architecture and application levels, including power consumption, silicon area/cost, latency, energy for a given application task, memory bottlenecks, manufacturing challenges and operating frameworks
- Extend the technology roadmap driven by Integrated Circuits (ICs) designed specifically for AI and Machine Learning (ML) applications by evaluating and demonstrating the applicability of emerging technologies able to provide scalable power, performance and area benefits
- Exchange wafers between foundries and participating RTOs to facilitate demonstration of functional neuromorphic chips, thereby allowing the use of the extensive know-how of European R&D organizations for future products, while maintaining contamination-free high volume production
- Quantify the capability of the most prevalent neuromorphic hardware implementations by targeting a broad algorithmic spectrum and isolating the critical sections of each algorithm; this would include Deep Learning (DL) inference (e.g. CNNs) and SNNs
- Enable the European semiconductor industry to maintain its position at the cutting edge of neuromorphic chip development.



IMPACT

The TEMPO project has had a strong impact because it provided hardware suitable for supporting complex situations specified by industrial partners in different fields (automotive, space, health, food, industrial, etc.). Different types of memory (magnetic, ferroelectric, resistive) can be benchmarked not only for demonstrators, but also for providing a scorecard for the ecosystem and for paving the way towards facilitating future recommendations for new applications. These actions will associate the best memory hardware solution to a given requirement based on different criteria in terms of power consumption, latency, resolution, etc. The TEMPO project partners also aligned their different assets, in terms of hardware equipment and processes, to their mutual benefit in long term cooperation especially by the three prime Research, Technology and Organisation (RTO) stakeholders, namely CEA-Leti and the Imec and Fraunhofer institutes. **From a long-term perspective, the TEMPO project opened up affordable, fast-track access for European SMEs and systems houses, which will have a key impact on European ecosystem sovereignty.**

Publications
The TEMPO project just started in May 2019.

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Alexandre Valentian
alexandre.valentian@cea.fr

Yannick Le Tiec
yannick.letiec@cea.fr

PHOTONICS DEVICES

COSMICC
HILICO
MASSTART
Mesmerise
MILEDI
PHABULOUS
PICTURE
PIXAPP
VIZTA

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COSMICC

Objectives

The COSMICC project partners are key, global industrial and research leaders in the fields of silicon photonics, CMOS electronics, printed circuit board packaging, optical transceivers and datacenters. They share a strong vision that mass commercialization of Si-photonics-based transceivers can now start by upgrading the existing photonic integration platform of project partner STMicroelectronics.
COSMICC is developing on-board optical transceivers and, by combining CMOS electronics and Si-photonics with innovative high-throughput fiber attachment techniques, the developed solutions can be scaled to meet future data transmission requirements in datacenters and super-computing systems. The targeted demonstrator features a high aggregated data rate of up to 2.4 Tb/s based on 12 fibers conveying 200 Gb/s per fiber, low power consumption of less than 2 pJ/bit and low cost (approximately 0.2-/bit).
Performance characteristics improved by an order of magnitude compared with current VCSEL transceivers and early establishment of a new value chain means that COSMICC technology can potentially satisfy massive market needs at a target cost per bit unmatched by conventional WDM transceivers.

http://www.h2020-cosmicc.com/

Keywords
3D photonic/electronic integration
Datacentre communications
High-speed optical transceivers
Mid-board integration
Multiple fiber attachment
Polymer waveguide
Silicon Photonics
Wavelength Division Multiplexing

COSMICC at a glance

48 months
Dec. 2015 > Nov. 2019

EC Programme
H2020-ICT-27-2015 “Photonics KET”

Project Coordinator
CEA-Leti (FR)

Partners
CH: Vario-Optics
FR: Ayming, STmicroelectronics, University Paris-Sud
GB: Cork Institute of Technology, Seagate (until April 2018), University St-Andrews, Univiversity Southampton
GE: Finisar
IT: STmicroelectronics, University Pavia

Total budget
€ 4 m.

EC Contribution
€ 3.7 m.

Contract Number
688516

CmOs Solutions for Mid-board Integrated Transceivers with breakthrough Connectivity at ultra-low Cost

The COSMICC project’s objective is to build cheap, low power optical communication systems. The project is therefore developing silicon microchips embedding photonic integrated circuits, which can send or receive high data volumes at very high speed conveyed by light in optical fibers.

CEA-Leti in COSMICC

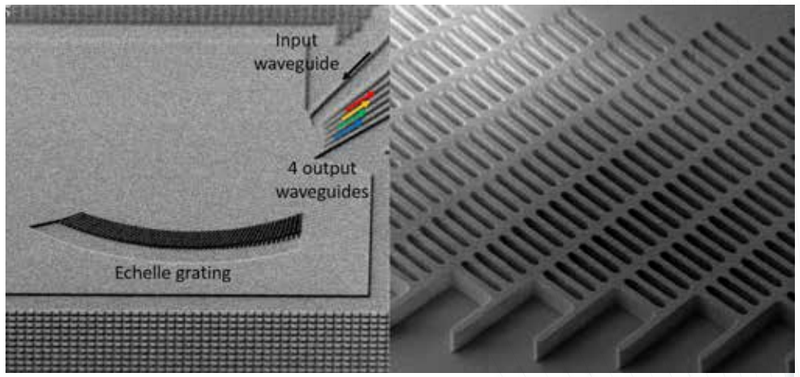
CEA-Leti is contributing to the COSMICC project by developing novel devices and integrated optical transceiver circuits capable of meeting the requirements of datacenter optical communication links based on Coarse Wavelength Division Multiplexing (CWDM).

The Institute has successfully completed technological developments to upgrade its 200 mm R&D Silicon Photonics platform with the introduction of a new SiN guiding layer integrated above the Si layer along with an intermediate SiO2 spacing layer. SiN material combines several benefits: 1) it is transparent across a broad range of wavelengths due to a refractive index lower than silicon (1.88 at 1310 nm wavelength), 2) it is less prone to fabrication defects thus reducing propagation losses and, 3) its refractive index is, by an order of magnitude, less sensitive to temperature than that of silicon, which makes it particularly attractive for building low-loss athermal devices.

CEA-Leti has developed a low temperature (300 °C)-deposited SiNx material to reduce mechanical stresses and ensure compatibility with doped active components such as high-speed modulators and photodetectors in the underlying Si guiding layer. Propagation losses of monomode SiN waveguides are as low as 0.8 dB/cm compared with 3.5 dB/cm for their Si counterparts. In addition, the transition between Si and SiN layers has been optimized to ensure losses of less than 0.1 dB.

This additional low-loss SiN layer has enabled CEA-Leti to develop several key components for CWDM (Coarse Wavelength Division Multiplexing) optical transceivers including a 4-wavelength athermal (de)multiplexer (1271, 1291, 1311 and 1331 nm) and a broadband hybrid SiN/Si fiber grating coupler over 80 nm.

CEA-Leti is also designing and integrating hybrid III-V lasers on the SiN-enhanced silicon photonics platform to manufacture fully integrated, uncooled, high-speed silicon photonics transceivers operating at 100 Gb/s per fiber.



Scanning Electron Microscope picture of a 4-wavelength demultiplexer based on an echelle grating design (left) overview of the device; (right) close-up on the high-resolution echelle grating with 200nm features and 200nm pitch.
© CEA-Leti

IMPACT

CEA-Leti has developed a state-of-the-art library of Si and SiN photonic devices that can be used to build photonic integrated circuits for Datacom applications. These developments have prompted creation of start-up SCINTIL Photonics and diversification towards new applications in LIDAR for automotive, High-Performance Computing (HPC) and quantum cryptography.

Publications
«A Versatile Silicon-Silicon Nitride Photonics Platform for Enhanced Functionalities and Applications», Q. Wilmart, H. El Dirani, N. Tyler, D. Fowler, S. Malhouitre, S. Garcia, M. Casale, S. Kerdiles, K. Hassan, C. Monat, X. Letartre, A. Kamel, M. Pu, K. Yvind, L. Oxenlowe, W. Rabaud, C. Sciancalepore, B. Szelag and S. Olivier, Applied Sciences, 9, 255 (2019).

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Ségolène Olivier
segolene.olivier@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr


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HILICO

HiLiCo

http://hilico.eu/

Keywords
Avionics
Brightness
CMOS
Cockpit
Full-colour
Gallium Nitride (GaN)
Integration
LED
Microdisplay
MicroLED
Monolithic
Quantum dot
Small pitch

HILICO at a glance

36 months
Jun. 2017 > May 2020

EC Programme
H2020-CS2-CFP04-2016-02

Project Coordinator
CEA-Leti (FR)

Partners
CH: Novagan
FR: CEA-Leti, Microoled, Nexdot

Total budget
€ 4.1 m.

EC Contribution
€ 4.1 m.

Contract Number
75549

High Luminescence in Cockpit

Emerging applications based on augmented reality are increasing the need for compact, very bright, energy efficient displays. The HILICO project is closely developing the future technologies required for this and its specific outcome will benefit the field of avionics by providing the next generation cockpit display system.

Objectives

There is growing market demand for high quality information displays in multiple application fields. This is particularly true in commercial avionics, in which high luminance displays capable of displaying readable information in a very bright environment are required. Today's technologies do not permit manufacturing of compact displays of the required brightness combined with very low power consumption. The purpose of the HILICO project is to develop a new generation of monochrome and full color emissive GaN micro-displays offering 1920 x 1200 pixel resolution (WUXGA), 8-µm pixel pitch, very high brightness (> 1MCd/cm²) and good form factor capabilities for designing a ground-breaking, compact, see-through system for next generation avionics applications. The project is taking up the following challenges:

- Development of high-quality, GaN-based, LED epilayers designed to fulfill targeted demonstrator performance characteristics
- Design and fabrication of an active matrix based on advanced, complementary, metal oxide semi-conductor (CMOS) technology to control each pixel
- Coupling of the LED structure and the CMOS to build a monolithic structure, on which high-precision LED arrays can be manufactured to build monochrome, active matrix, high-resolution GaN microdisplays
- Addition of color converters (quantum dots and 2D Multi-Quantum Wells layers) on blue emitting devices for manufacturing bi-color and full-color display demonstrators
- Design and manufacturing of the electronics followed by testing and assessment of the completed microdisplay device. First demonstrators will be qualified for future commercialization.

The project consortium brings together an RTO, a major manufacturer and two SMEs. It has received a grant of 4,091,583 > with an effort of 283 person-months (PM).

CEA-Leti in HILICO

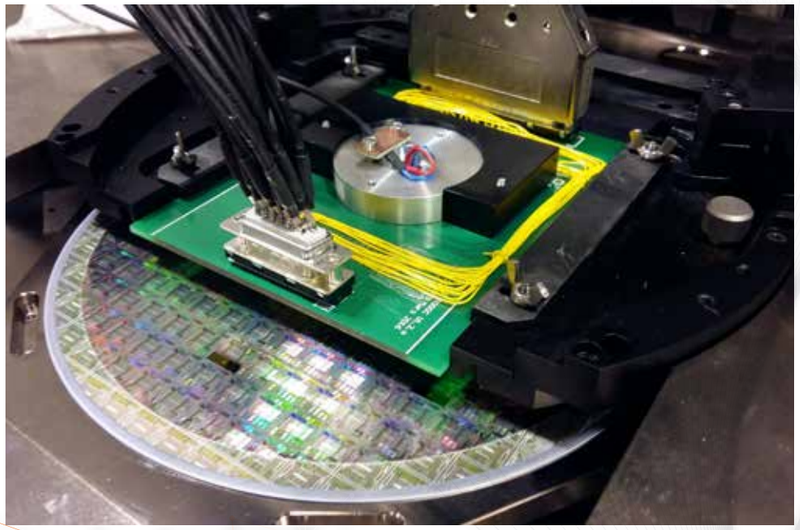
At the project halfway point, progress has been good in relation to most of the technologies required for manufacturing LED microdisplays.

- Fully optimized, blue LED epilayers have been grown by Novagan to provide a 10µm-pitch matrix using micro-LEDs exhibiting an external quantum efficiency that exceeds 9% at 3V and an emission wavelength variation reduced by a factor of 3 (±4 nm). Both these performance characteristics are closely in line with application requirements for reaching the expected brightness of 1Mcd/m2.

- While more complex than expected, the CEA-Leti-developed architecture of the CMOS backplane circuit is now ready for building the tape-out circuit.

- Coupling of the LED and CMOS has been demonstrated on the CEA-Leti technological platform. As a proof of concept, the Novagan-supplied GaN epilayer has been transferred to an 8" Si wafer and 8µm pixel/10µm pitch LED arrays have been successfully processed.

- Different light conversion strategies have been assessed, paving the way to efficient light converters:
  - 2D conversion layers: blue-to-green conversion layers based on InGaN/GaN Quantum Wells (30 x QW) have been grown on sapphire substrates by Novagan. Blue absorption of 1 % per QW means that light trapping architecture will be required at pixel level. Similarly, AlInGaP QW, blue-to-red conversion layers have been successfully transferred to sapphire substrates. While optical measurements on a CEA-Leti dedicated optical bench have indicated blue-to-red down conversion, the observed strong light guiding effect suggests dedicated light extraction structures to be implemented at pixel level (under investigation at CEA-Leti)
  - Quantum dots: as an alternative approach, photo-patterned resin layers containing 2D nanoplatelets (NPL) has also been considered. More absorbent, stable core-shell NPLs have been successfully synthesized at NEXDOT and first photo-patterning of red NPL/resist composite has been demonstrated on the CEA technological platform with pixel pitch resolution down to 10µm.



CEA dedicated IVL measurement set-up: pixel emission statistical analysis.
© CEA-Leti

IMPACT

The technology developed within the HILICO project is contributing to greater European competitiveness through rapid, massive deployment of innovative products on the microdisplay market along with head-up displays, head-mounted displays and smart eyewear devices.

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Etienne Quesnel
etienne.quesnel@cea.fr



MASSTART

https://masstart.eu/

Keywords
Assembly, Automation
Data Center Interconnect
Manufacturing
Optical Communications, Packaging
Photonics
Photonic Integrated Circuits
Pigtailing, Silicon
Testing
Transceiver

MASSTART at a glance

36 months
Jan. 2019 > Dec. 2021

EC Programme
Horizon 2020

Project Coordinator
Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE)

Partners
DE: Adva Optical Networking SE, Ficontec Service GmbH, Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V., Tektronix GmbH
FR: CEA-Leti
GR: Aristotelio Panepistimio Thessalonikis
IL: Dustphotonics Ltd, Mellanox Technologies Ltd
NL: Bright Photonics BV

Total budget
€ 7.4 m.

EC Contribution
€ 5.9 m.

Contract Number
825109

Mass Manufacturing of Transceivers for Terabit/s era

Cheap, high-speed photonic components are required to cope with today's boom in data communications, especially optical communications at Data Centers. The MASSTART project's aim is to transform holistically the assembly and characterization of high-speed photonic transceivers, thereby drastically reducing their mass production cost. This will guarantee European leadership in the photonics industry for the next decade.

CEA-Leti in MASSTART

CEA-Leti's main objectives within the MASSART project are to:

• Provide access to its Photonic Device Library (Design Kit) for other project partners in order to build PICs using CEA-Leti's building blocks

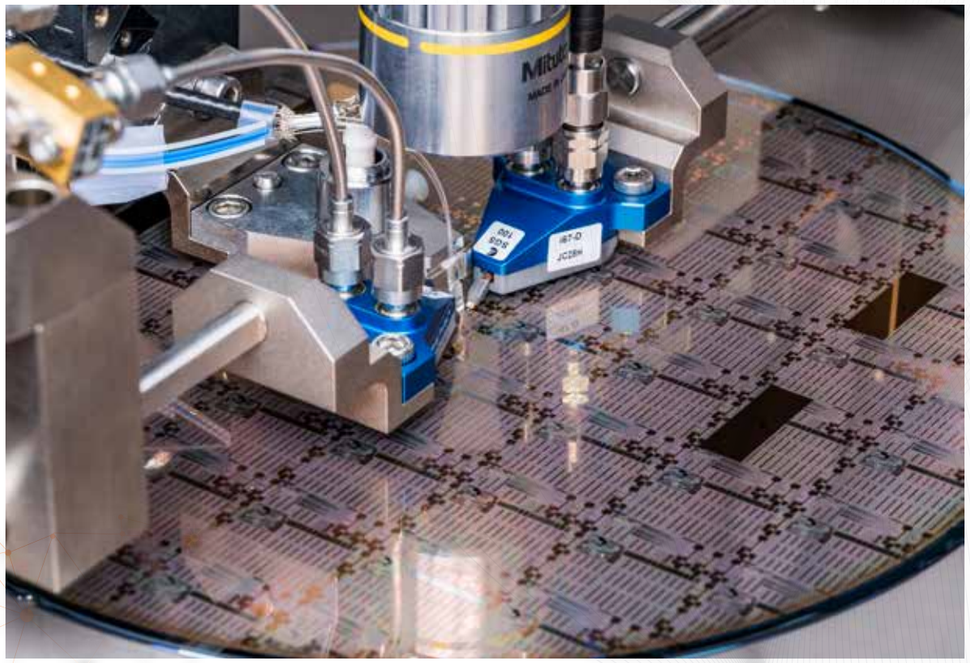
• Control the resulting designs and proceed with lithographic mask procurement

• Perform wafer manufacturing of SOI photonic circuits and on-wafer characterization using state-of-the-art testing equipment

• Participate in common project activity such as specifications, standardization, dissemination and technical discussions on design and assembly.

Objectives

The MASSTART project is focusing on holistically transforming the assembly and characterization of high-speed photonic transceivers to reduce their mass production cost to -1/Gb/s or even less. This is being achieved by using enhanced scalable methods, specifically i) glass interface-based laser/Photonic Integrated Circuit (PIC) and fiber/PIC coupling and leveraging glass waveguide technology to obtain spot size and pitch converters for dramatically increasing optical I/O density, while facilitating automated assembly processes, ii) 3D packaging (TSV) enabling backside connection of high-speed PIC to an Si carrier, iii) a new generation of flip chip bonders with enhanced placement in a full assembly line compatible with Industry 4.0 to guarantee a sixfold improvement in throughput and, iv) wafer-level evaluation of assembled circuits using novel tools to reduce characterization time by a factor of 10 (down to 1 minute per device). This process flow will be assessed through fabrication and characterization of four different demonstrators, which will address the medium term requirements of next generation transceivers required by Data Center operators for inter- and intra-Data Center applications. The demonstrators are: i) a 4-channel, PSM4 module in QSFP-DD format with a 400G aggregate bit rate, ii) an 8-channel, WDM module in a QSFP-DD format with a 800G aggregate bit rate, iii) a 16-channel, WDM on-board module delivering a 1.6Tb/s aggregate line rate and, iv) a 600Gb/s, tunable, single-wavelength, coherent transceiver based on the DP-64QAM modulation format on a 64Gbaud/s line rate. Finally, MASSTART is aiming for close interaction with international bodies to ensure developed technology compliance and standardization with other proposed packaging.



Automated probed testing of a silicon photonics wafer.
© CEA-Leti

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Stéphane Bernabé
stephane.bernabe@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



Mesmerise

Multi-Energy High Resolution Modular Scan System for Internal and External Concealed Commodities

The aim of the MESMERISE project is to detect drugs ingested by smugglers. A dedicated method implementing a photon counting multi-energy detector have allowed us to detect such packages subject to minimum radiation exposure. Experimental results have demonstrated the system's capacity to reveal drug packages inside the human body.

http://h2020mesmerise.eu/

Keywords
Border control
Low dose radiography

LUMINT at a glance

36 months
May 2016 > Apr. 2019
+ extension

EC Programme
H2020-BES-2014-2015

Project Coordinator
Universidad de Alcala (ES)

Partners
BLR: Adani
DE: BPE e.K.
ES: Ciemat,Ministerio del Interior, San Jorge Tecnlogicas SL
FR: CEA, Multix SA
NOR: Tollregion Oslo og Akershus
RO: Universitatea Dunarea de Jos din Galati
UK: Home Office

Total budget
€ 5 m.

EC Contribution
€ 5 m.

Contract Number
700399

Objectives

MESMERISE has enabled new technologies to be developed and tested (ultra low dose Multispectral X-ray transmission and Infrasonic interrogation) for non-intrusive scanning. The ultimate aim was to detect automatically and identify internally and externally concealed commodities entirely independently of human operator interpretation and training.

A novel x-ray detector featuring higher imaging resolution captures 256 channels of X-ray spectroscopic information, prompting a step change in material identification. Crucially, this resolution level allows enhanced detection of narcotics and explosives concealed in the body; a highly complex issue with currently available equipment.

A second subsystem for detecting externally concealed items based on new, intrinsically safe, technology (infrasound near-field acoustic holography) is entirely new to security screening. Low-frequency MEM micro-technology is implemented to ensure an automated no-contact pat-down function.

The two subsystems operate independently or together to provide complementary information and enhance detection of externally concealed objects. Automated algorithms for each subsystem and data fusion techniques for the combined system identify chemicals, recognize patterns and detect anomalies in any part of the body, including prosthetic elements or plasters, above a 100g threshold.

A clear exploitation route is ensured by a major body scanner manufacturer, several SMEs, universities, R&D centres, end-users and a diverse, high-quality external advisory board offering broad international input and a direct link to US counterparts.

Acceptance by society has been promoted by communications highlighting MESMERISE's contactless nature and non-requirement for operators to view explicit images. The system is intrinsically respectful of personal dignity and privacy.

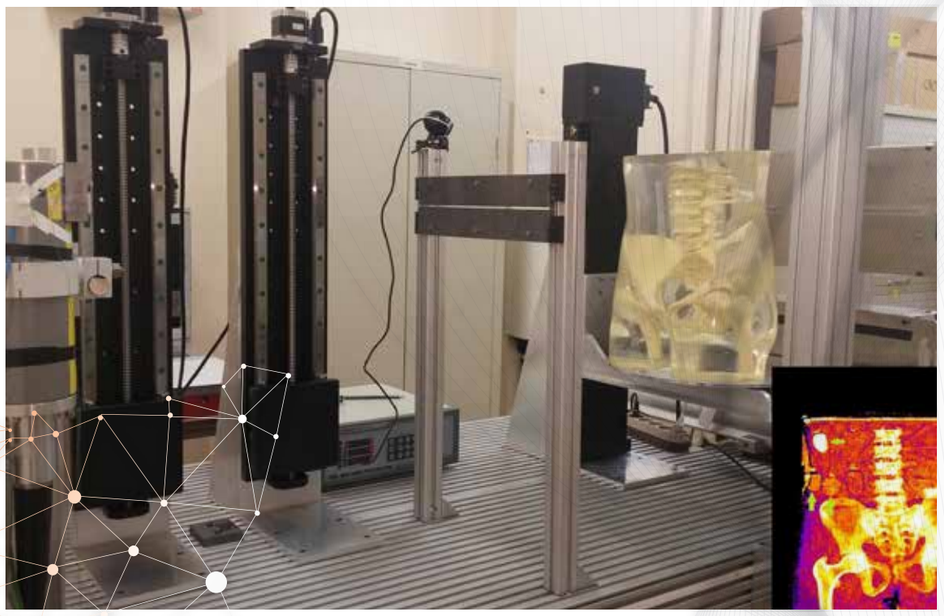
CEA-Leti in Mesmerise

The project aim was achieved by using a X-ray photon counting multi-energy detector. This new technology developed by CEA-Leti and transferred to spin-off MultiX provides valuable information for an optimised radiation dose.

CEA-Leti had knowledge of the detector and the know-how for using the multi-energy information for a specific security application (airport luggage control). But the existing algorithms were unsuitable for very low dose conditions and initial images were too noisy.

We had to imagine, develop and test a dedicated «multiscale decomposition» method, which is suited to human body inspection.

This method was initially developed using the simulation tools available at the CEA-Leti laboratory. It was then validated experimentally on CEA-Leti's test bench; this confirmed the system's capacity to reveal the presence of drug packages ingested by smugglers. A scanning gantry was built, incorporating 10 multi-energy detectors (ME 100) supplied by MultiX, for system validation using pig carcasses and corpses.



Validation on CEA-Leti's test bench from detector and method, showing the system ability to reveal the presence of drug packages ingested by smugglers.
© CEA-Leti

IMPACT

This project fell within the scope of CEA-Leti's promotion of the multi-energy technology transferred to MultiX.
MESMERISE developments have demonstrated the contribution of this technology to body scanning. If customs authorities (consortium members) validate the concept, this project could lead to Adani's integration of the MultiX detector into its body scanning gantries.

TRL
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Vincent Moulin
vincent.moulin@cea.fr



MILEDI

Objectives

The MILEDI project is targeting fabrication of micro light-emitting diodes (mQDL) and micro organic light-emitting diodes (mQDO) using direct laser or electron beam patterning of nanometer scale Quantum Dots (QDs) to write the Red-Green-Blue (RGB) arrays for display production.

The main idea underpinning the project is to form the colored, green-red, light-emitting QDs directly over a matrix of blue, emitting micro QDL/QDO arrays such that the QDs act as frequency down-converters and constitute an RGB microdisplay. Both direct writing technologies will be fully developed to optimize the QD light emission spectrum of the display and its stability. Patterning resolution is expected at micrometric scales, depending on the laser spot areas and particle beam dimensions and operation. These methods, in conjunction with direct QD formation, will ensure highly flexible, simple manufacturing processes based on few steps and low chemical impact. The MILEDI approach for micro QDL and QDO RGB displays manufactured by direct laser/electron beam QD patterning will be validated by building a final prototype of Rear Projection display through the existing project supply chain.

MILEDI
Micro Quantum Dot-Light Emitting Diode/Organic Light Emitting Diode - Direct patterning

https://www.miledi-h2020.eu/

Keywords
Electron Beam Patterning
Laser Patterning
LED
OLED
Quantum Dots

MILEDI at a glance

42 months
Jan. 2018 > Jun. 2021

EC Programme
H2020-ICT-2017-1

Project Coordinator
Enea (IT)

Partners
DE: Fraunhofer Institute, Technical University of Dresden
FR: CEA-Leti, Microoled
GB: University of St Andrews
IL: Amsys
IT: Enea, Fiat Research Center, University of Modena and Reggio Emilia
LT: Ekspla

Total budget
€ 4.1 m.

EC Contribution
€ 4.1 m.

Contract Number
779373

Micro Quantum Dot Light-Emitting Diode and Organic Light-Emitting Diode - Direct Patterning

The MILEDI project aims to develop ultra-small displays based on micrometer scale red, green and blue LED pixel arrays. These displays are projected to be integrated into car dashboards to provide efficient, luminous, interior screens.

CEA-Leti in MILEDI

CEA-Leti's contribution to the MILEDI project involves developing blue, micro-LED arrays, preparing them for quantum dot layer coating and laser patterning, and assessing their corresponding color conversion efficiency.

During the initial project period, CEA-Leti has mainly taken color conversion measurements on luminescent materials provided by the different project partners to select the best candidate for producing red or green pixels. Several QD compositions have been tested (Cd-based and Cd-free nanoparticles) and preliminary aging has been performed to assess the material stability under luminous flux.

Micro-LED array manufacturing has also started. The main concern has been to remove the GaN growth sapphire substrate to provide high-contrast pixelated blue LED arrays. A number of trials has been conducted on mechanical samples (at chip and wafer levels) and their results will soon be reproduced on functional LED arrays.

Upcoming project work will be dedicated firstly to implementing a laser patterning technique on these LED arrays to grow locally red and green quantum dots within in a polymer host matrix deposited on GaN and secondly to directly obtaining red-green-blue micro-displays.



A commercial blue LED covered with QD for conversion efficiency assessment.
© CEA-Leti

IMPACT

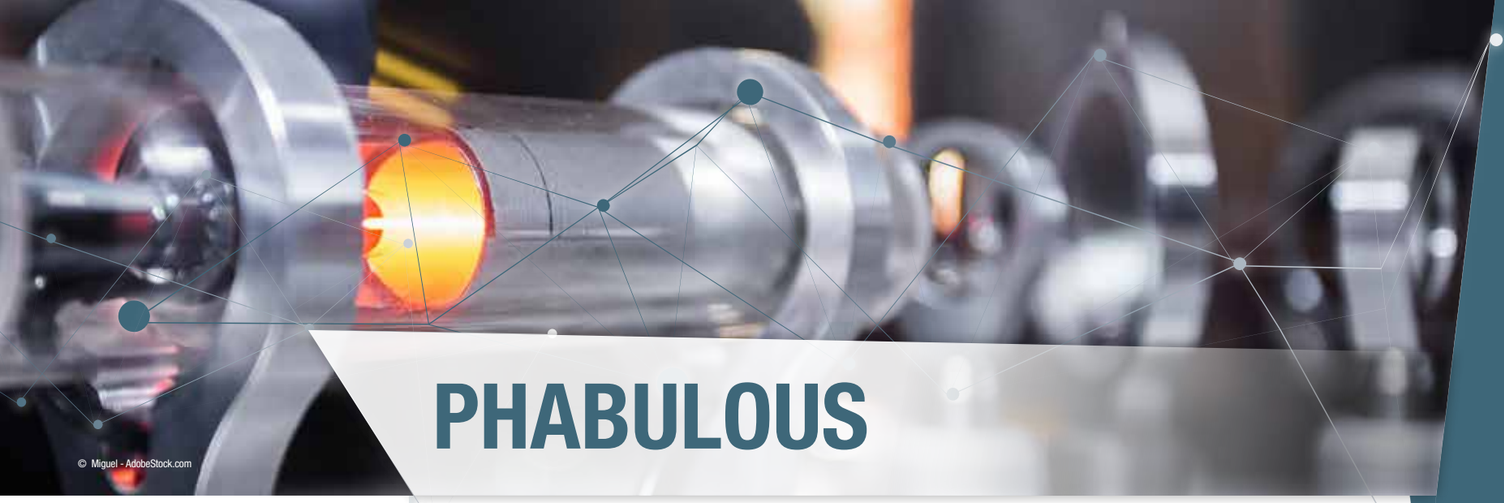
The expected outcome of the program will be to enable European manufacturers to:

- Market highly competitive products by integrating wearable visualization for systems and user-centric services in business cases involving personal health care, lifestyle, sports, smart cities, smart home and 5G connectivity
- Build a Europe-centered value chain by strengthening domestic manufacturing of optical and semiconductor components and software for typical telecom, medical, sports and eyewear systems.

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Etienne Quesnel
etienne.quesnel@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



PHABULOUS

Objectives

Industrial demand for Free-Form Microlens Arrays (FMLAs) is a market reality today. However, high access barriers to pre-commercial production capabilities in Europe have prevented companies, especially SMEs, from commercially exploiting FMLA technology. The aim of the PHABULOUS project is to set up a self-sustainable pilot line for designing and manufacturing FMLA solutions and for integrating them into high added-value products. The project consortium is translating urgent, high-impact industrial needs into industrially relevant predictive software packages, manufacturing tools and processes, and characterization methods for in- and off-line quality inspection and integration schemes; these developments are all necessary to successful demonstration involving pre-commercial production runs. More specifically, the PHABULOUS project aims are to:

1 • Mature FMLA manufacturing processes and functionalities from current technology readiness level TRL 5 to TRL 7 and to raise the pilot line's overall level of manufacturing readiness from MRL 5-6 to MRL 8-9 by: 1/ adapting predictive algorithms to simulation packages, 2/ optimizing different ultra-precision micromachining technologies for manufacturing high-quality FMLAs, 3/ optimizing high-throughput UV imprint technologies, 4/ integrating a surface coating technique portfolio and, 5/ optimizing the metrology procedure

2 • Implement six industrial use-cases demonstrating pilot manufacturing in their operational environment

3 • Establish an open-access, sustainable, distributed pilot line infrastructure with a single entry point

4 • Validate the pilot line services through implementation of 20 industrial pilot cases.

Keywords
Free-form micro-optics
Micro-manufacturing tools
Micro-optics design
Pilot line production UV imprint technologies, Roll-to-Plate, Roll-to-Roll, UV-NIL lithography/replication
Wafer scale

PHABULOUS at a glance

48 months
Jan. 2020 > Dec. 2024

EC Programme
H2020-ICT-03-2018-2019

Project Coordinator
CSEM Center Muttenz (CH)

Partners
AU: D. Swarovski KG Austria, Joanneum Research Forschungsgesellschaft MBH Austria, Seisenbacher GmbH, Zumtobel Lighting Gmgh
BE: Laser Engineering Applications SA, Wielandts Ultra Precision Machining Technologies
CH: Centre Suisse d'Electronique et de Microtechnique SA - Recherche et Développement, Suss Microoptics SA
DE: Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung E.V., Hella Gmbh & Co KGAA
ES: Limbak 4PI SL
FI: Nanocomp Oy Ltd, Teknologian tutkimuskeskus VTT Oy
FR: CEA, European Photonics Industry Consortium, Microoled SARL
GB: PowerPhotonic Ltd
NL: MORPHOTONICS BV
SK: AMIRES SRO Czech Republic

Total budget
€ 17.5 m.

EC Contribution
€ 14.9 m.

Contract Number
871710

Pilot-line providing highly advanced & robust manufacturing technology for optical free-form microstructures

The urgent need to provide miniaturized optical components has been driving the exponential growth of the micro-optics market over the last decade based on an increasing need for free-form micro-optics to address the challenges of the photonics market over the coming five to ten years.

CEA-Leti in PHABULOUS

Aim of the project is to set up a self-sustainable pilot line for designing and manufacturing FMLA solutions and for integrating them into high added-value products.

With its unique photolithography platform, CEA-Leti is contributing to the pilot line operation processes by offering its knowledge of designing and limiting processes so as to define and validate, in conjunction with the industrial partner, the best technology for the master origination process.

One of the first applications identified with CEA-Leti's MICROOLED partner is Si-etching-based origination for manufacturing masters, then performing chip-to-wafer integration of the final free-form lenses on the microdisplay to improve light extraction.

For other new cases, the procedure is as follows:

• Define methods for selecting and supporting pilot cases

• Provide subsidized support of up to 20 pilot cases using the €3M Pilot Case Fund, thereby mitigating the early adoption risk

• Validate the PHABULOUS pilot line open-access business model and services.
The outcome of this work will be published and presented to the scientific and industrial community to isolate new business cases compatible with PHABULOUS pilot line technologies.



IMPACT

Ultimate aim of PHABULOUS is to create the infrastructure for pilot manufacturing of FMLAs, which can accelerate their market introduction and unlock multiple applications. The ecosystem represented by PHABULOUS is a particularly strong, comprehensive value chain of material suppliers, technology providers, RTOs, pilot line facility providers and product integrators/end-users.

TRL
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Hani Kanaan
hani.kanaan@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



PICTURE

Objectives

The PICTURE project is developing photonic integration technology by bonding multi-III-V-dies of different epitaxial stacks to SOI wafers with a thinner, uniform dielectric bonding layer. This heterogeneous integration platform is expected to give higher performance lasers and photo-detectors based on the optimized III-V dies. Moreover, the thinner bonding layer could lead to outstandingly performant MOSCAP III-V/Si modulators and to a new generation of wavelength tunable, distributed feedback lasers. The overall process including the SOI process, bonding, III-V and back-end process is being developed on a 200mm R&D CMOS line to give higher yield, smaller footprint and lower cost PICs. Two types of PICs with a total capacity of 400Gb/s are currently being developed and will soon be packaged and validated in system configuration.
The PICTURE project is also developing direct growth of high-performance quantum dot lasers and selective area growth on bonded templates for the future generation of high-density PICs.
The project is coordinated by III-V Lab and its partners include the University of Southampton, CEA, University College London, Imec, Tyndall, Argotech and Nokia Bell Labs. This consortium is highly complementary and embraces all the skills required to fulfill the project objectives: growth of semiconductor materials, silicon process and III-V process, PIC design and characterization, PIC prototyping and assessment in high-bit-rate digital communication systems.
Beyond the consortium's capacity to fulfill the project objectives, its partners have the potential to set up a comprehensive supply chain for future usage of project results either "in house" or by establishing suitable partnerships.

http://picture-h2020.eu/

Keywords
III-V photonics
Communication technology
High-frequency technology
Manufacturing technologies for photonic devices
Nanophotonics
Nano-processes
Optical Communications
Silicon photonics

PICTURE at a glance

36 months
Jan. 2018 > Dec. 2020

EC Programme
H2020-ICT-2017-1 (Information and Communication Technologies)

Project Coordinator
III-V Lab (FR)

Partners
BE: Imec
CZ: Argotech
FR: III-V Lab, CEA-Leti, Nokia
GB: SOTON, UCL
IE: Tyndall

Total budget
€ 4 m.

EC Contribution
€ 3.9 m.

Contract Number
780930

High Performance and High Yield Heterogeneous III-V/Si Photonic Integrated Circuits using a Thin and Uniform Bonding Layer

The aim of the PICTURE project is to develop on-chip technology capable of generating light, encoding data at very high speed and emitting and collecting this light through optical fiber.

CEA-Leti in PICTURE

CEA-Leti contribution to the PICTURE project

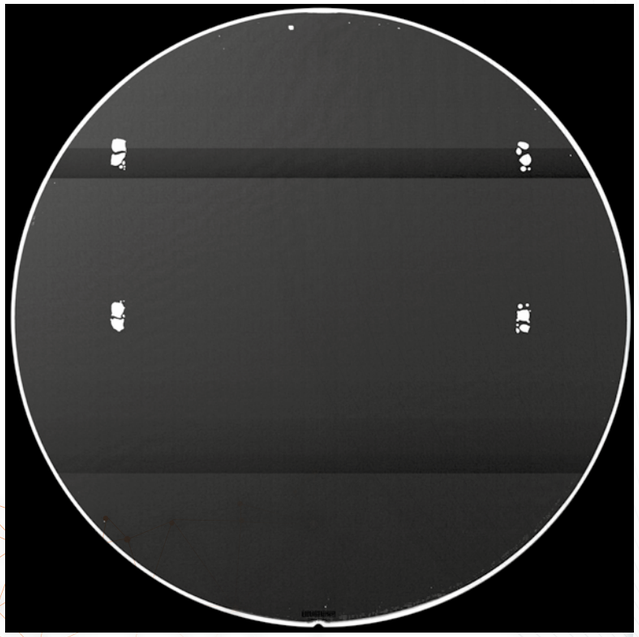
• Enhancement of its 200 mm silicon photonics platform by implementing a new III-V on-silicon hybrid bonding scheme using a thin oxide bonding layer to produce optimized hybrid active devices such as hybrid III-V on Si lasers. These offer improved power efficiency and thermal behavior, very efficient, low-power consumption, III-V on Si hybrid capacitive modulators and photodiodes.

• **Patterning, encapsulation and planarization of silicon photonics devices has been successfully optimized to obtain a high bonding yield in 20 mm on thin oxide (~20nm) as shown in the scanning acoustic microscope image, in which the black areas represent successfully bonded interfaces.**

• The newly developed planarization steps involve a sequence of chemical and mechanical polishing and thin oxide deposition optimized to ensure high uniformity and selectivity above the silicon on insulator waveguides.

• Multi-die bonding technology was also developed to use expensive III-V material only where it is necessary for active devices and to use III-V epitaxial stacks based on QW or QD active layers separately optimized for the laser, the modulator and the photodetector.

The entire fabrication process of III-V on Si photonic integrated circuits is expected to be demonstrated on CEA-Leti's 200 mm CMOS platform by the end of the project to confirm industrial manufacturability. In addition, CEA-Leti's know-how in designing efficient, low-voltage, low power consumption modulators has been implemented to co-design hybrid III-V on Si modulators with the project partners. Characterization of all the passive and active building blocks up to 67 GHz operation on its Automatic Prober stations is planned for when the first devices become available.



Scanning Acoustic Microscopy image of a 200mm SOI wafer bonding interface on a 20nm-thin oxide.
© CEA-Leti

IMPACT

Photonic integration technology developed in the PICTURE project will allow mass production, high yield, small footprint and low cost for a new generation of PICs jointly exploiting the advantages of III-V and silicon materials. This technology will demonstrate short-reach WDM PIC, requiring high volume manufacturing and long-reach coherent PIC targeting a smaller market. The consortium is ready to supply PICTURE-based PICs to the market, therefore contributing to strengthen the Europe's position as a market leader for the most advanced, chip level, integrated solutions.

Publications

• *«Gate Oxide Process for III-V / Si Hybrid MOS Capacitor Modulator», S. Malhouitre, V. Ramez, V. Muffato, Y. Desières, K. Hassan, Submitted to IEEE Group IV Photonics Conference, Singapore, 2019.*

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Karim Hassan
karim.hassan@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



PIXAPP

PIXAPP Photonic Packaging Pilot Line

www.pixapp.eu

Keywords
Integrated Optics
Microbumps
Packaging
Photonics, Platform
Self-alignment

PIXAPP at a glance

48 months
Jan. 2017 > Dec. 2020

EC Programme
H2020-ICT-29-2016

Project Coordinator
University College Cork (IE)

Partners
BE: IMEC
CZ: Argotech AS
DE: Ficontec Service, Fraunhofer HHI, Karlsruhe Institute of Technology, Microfluidic Chipshop
FL: VTT
FR: III-V Lab, CE-Leti, EPIC
IRE: Eblana Photonics Ltd, Tyndall National Institute
IT: Linkra
NL: Phoenix BV, Technobis IPPS, TU Eindhoven, XiO Photonics BV
UK: Randox Laboratories

Total budget
€ 15.6 m

EC Contribution
€ 13.4 m.

Contract Number
731954

Photonic Integrated Circuits Assembly and Packaging Pilot Line

«Photonic packaging» is a generic term that embraces all the domains needed to materialize the link between components and systems. The PIXAPP project aim is to develop a platform grouping together partners with different expertise to provide solutions to packaging problems that cannot be solve by one supplier alone.

Objectives

The PIXAPP project has established the world's first open access, Photonic Integrated Circuit (PIC), pilot assembly and packaging line. It combines a strong interdisciplinary team of Europe's leading industrials and research organizations. PIXAPP is providing Europe's SMEs with a unique one-stop shop, enabling them to exploit the breakthrough advantages of PIC technologies. PIXAPP bridges the «valley of death» by providing SMEs with an easy access route to taking R&D results from laboratory to market and giving them a competitive advantage over global competition. Target markets include communications, healthcare and security, which are of major socio-economic importance to Europe. PIXAPP's manufacturing capabilities can support over 120 users per year across every manufacturing stage from prototyping to medium scale production. PIXAPP bridges gaps in the value chain from assembly and packaging to equipment optimization, testing and application demonstration. In achieving these ambitious objectives, PIXAPP has fulfilled the following actions:
1) Combining a group of Europe's leading industrials and research organizations at a pilot line facility ensuring advanced PIC assembly and packaging
2) Developing an innovative pilot line operational model that coordinates activities between consortium partners and supports easy user access through a single entry point
3) Establishing packaging standards that provide cost-efficient assembly and packaging solutions, enabling transfer to full-scale industrial production
4) Mobilizing the highly skilled workforce required to manage and operate these industrial manufacturing facilities
5) Developing a business plan to ensure pilot line sustainability and a route to industrial production. PIXAPP delivers significant impacts to a wide stakeholder group, highlighting how industrial and research sectors can cooperate to address emerging socio-economic challenges.

CEA-Leti in PIXAPP

In this project, CEA-Leti intends to develop and transfer an innovative method for self-aligning micro-lens arrays on PIC wafers. This will lead to low cost and mass production compatible optical assembly of photonic devices for various applications (from optical fiber high-speed modules to biosensors). These developments will enable accurate alignment (<1µm) of micro-lenses used to collimate or refocus the output beam.

Assessment of the proposed technology has started through groundwork on micro-lenses and PIC to ensure the best assembly. Micro-lens wafers sourced from a PIXAPP partner are post-processed to obtain pads specifically sized for self-alignment, while microbumps are grown on PIXAPP reference PIC wafers processed by IMEC. After performing this work, an assembly process is developed using self-alignment to ensure micro-lens array placement with an accuracy of less than 1µm, a perfectly clean optical surface and homogeneous underfilling to minimize optical losses. This process is controlled by physical analysis to characterize residual misalignment; optical characterization is then performed to analyze the output beam and validate the micro-lens optical design.

At development stage, this assembly process is performed on SET sub-micron alignment equipment. The accuracy of this equipment allows evaluation of the maximum acceptable initial misalignment before reflow that can be rectified by self-alignment. This parameter will determine the placement speed of micro-lens arrays on PICs for mass production.

Once the technique has been demonstrated on reference and demonstrator chips, it will be transferred to the PIXAPP partners and proposed as an available assembly method on the PIXAPP platform.



Nanosystec fibre assembly equipement.
© CEA-Leti

IMPACT

The PIXAPP project is developing the first European photonic packaging platform offering customers mature solutions for photonic system design, development and manufacturing. CEA-Leti's cooperation involves developing technological blocks as future solutions to specific customer requirements (e.g. mass production effective optical assembly using reliable materials within the project scope), allowing the PIXAPP platform to continue offering up-to-date solutions in the coming years.

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Laurent Mendizabal
laurent.mendizabal@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



VIZTA

Objectives

The key, differentiating, 12» silicon sensing technologies developed in the VIZTA project embrace:
- Innovative sensors for SPAD and lock-in pixel for time-of-flight architecture
- On-chip solutions involving unprecedented, cost-effective NIR and RGB-Z filters
- Complex RGB+Z pixel architectures for multimodal 2D/3D imaging
- Advanced VCSEL sources including wafer-level GaAs optics and associated high-speed driver for short-range sensors.

These differentiating technologies allow development and validation of innovative 3D imaging sensor products using the following highly integrated prototype demonstrators:
- High resolution, time-of-flight ranging sensor module with integrated VCSEL, drivers, filters and optics
- Very high resolution (VGA min) depth camera sensor with integrated filters and optics.

With regard to medium- and long-range sensing, VIZTA also addresses new LiDAR systems with dedicated sources, optics and sensors. Technological development of sensors and emitters is conducted by leading semiconductor product suppliers (ST Microelectronics, Philips, III-V Lab) with the support of equipment suppliers (Amat, Semilab) and CEA-Leti RTO. The VIZTA project also features development of six demonstrators for key applications in the automotive, security, smart building, mobile robotics for smart cities and Industry 4.0 sectors based on a strong combination of industrial and academic partners (Ibeo, Veoneer, Ficosa, Beamagine, IEE, DFKI, UPC, Idemia, CEA-List, ISD, BCB, IDE, Eurecat and FCC). The VIZTA consortium brings together 23 partners from 9 European countries: France, Germany, Spain, Greece, Luxembourg, Latvia, Sweden, Hungary, and the United Kingdom.

https://www.vizta-ecsel.eu

Keywords
3D Integration, Artifical Intelligence, Biometrics, Components, Electronics, Heterogeneous Integration, Industry4.0, LiDARs, Micromirrors, Optical Phase Array, Optoelectronics, Photonics, Security, Semiconductors, Single Photon Avalanche Diode, Smart buildings, Time Of Flight, VCSEL

VIZTA at a glance

42 months
Mai 2019 > Oct.2023

EC Programme
H2020-ECSEL-2018-1-IA

Project Coordinator
STMicroelectronics Grenoble 2 (FR)

Partners
DE: DFKI German Research Centre for Artificial Intelligence, Ibeo Automotive Systems, Philips Photonics
ES: Alter Technology, Bcb Informatica Y Control, Beamagine, Eurecat, Polytechnic University of Catalonia
FR: III-V Lab, Applied Materials, CEA-Leti, CEA-List, Idemia, Lumibird, ST Microelectronics Crolles 1, ST Microelectronics Crolles 2, ST Microelectronics Grenoble
GB: ST Microelectronics
GR: ISD Integrated Systems Development
HU: Semilab
LU: IEE International Electronics and Engineering
LV: EDI Institute of Electronics and Computer Science
SE: Veoneer

Total budget
€ 86.3 m.

EC Contribution
€ 21.4 m.

Contract Number
826600-2 (Proposal Number)

Identification with Z-sensing Technologies and key Applications, Vision

The VIZTA project objectives are to develop innovative technologies in the field of optical sensors and laser sources for short- to long-range 3D-imaging and to demonstrate their value in several key applications in the automotive, security, smart building, mobile robotics for smart cities and Industry 4.0 sectors.

CEA-Leti in VIZTA

CEA-Leti occupies a central role in the VIZTA project through its:

- Support to ST Microelectronics in achieving **industrial maturity** of a new generation of **single photon avalanche diodes** and **indirect time-of-flight pixels** for short-distance 3D-imaging. TCAD studies, pixel simulation and design, testing, characterization and assistance in specific technological steps have been conducted in CEA-Leti cleanrooms

- Study and silicon-based validation of complex **RGB+Z pixel architectures for multimodal 2D/3D imaging**. Architectures based on lock-in or SPAD pixels for depth sensing (including rolling or global shutters for the RGB imager) based on monolithic or 3D integrations using a depth sensing pixel in place of a green pixel or a full Bayer have been considered. CEA-Leti is also in charge of **full color image** reconstruction, i.e. interpolation of missing color components along with edge detail conservation, artefacts and noise reduction

- Simulation, design and 12» wafer fabrication of the **optical stacks** including **microlenses** (gapless, diffractive and inner microlenses) and **filters** for the 3D and multi-modal innovative imagers fabricated during the project

- Investigation of new **3D integration** schemes including Face-to-Back and the opportunity to include small-size TSV connections (typically 1 µm diameter)

- Research related to optimization of a **silicon photonics integrated circuit** offering an optical phase array function for **medium-range automotive Lidars**

- Development of **1D and 2D MEMS micromirrors** with a new actuation system for long-range automotive Lidars.



12-inch optical filters deposition equipment.
© CEA-Leti

IMPACT

The VIZTA project represents a prime opportunity for establishing Europe as a leader and worldwide supplier of advanced 3D imaging sensors and systems. This is being achieved through total control of the entire value chain from Si technologies and heterogeneous integration to system equipment makers. VIZTA is strengthening the innovation and competitiveness of its partners, in particular by enabling large volume production of high-end imaging sensors based on STMicroelectronics' wafer production capacity in Crolles, France.

TRL
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Alexis Rochas
alexis.rochas@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr

POWER ELECTRONICS

3Ccar
5E
ModulED
NENUFAR

Photo courtesy of AdobeStock.com


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3Ccar

https://www.3ccar.eu/

Keywords
Automotive powertrain, Complexity control, Electric motor, Electrified vehicles, Electronic components, Embedded systems, Energy efficiency, Power electronics, Semiconductor, Smart cell

3Ccar at a glance

41 months
Jun. 2015 > Oct. 2018

EC Programme
ECSEL-FP7

Project Coordinator
Infineon Technologies (DE)

Partners
BE: On Semiconductor Belgium, Tenneco Automotive Europe
DE: Advantec, AVL, BMW., Daimler, Fraunhofer FhG-IISB, Fraunhofer FhG-IPA, Infineon Technologies, NXP Semiconductor, Offis, Siemens, Technische Universitaet Dresden
FR: CEA, Hutchinson, STMicroelectronics, Valéo
IT: CNR, Ideas&Motion srl, IFEVS, Solbian Energie Alternative srl, Torino e-District Consorzio, Università di Pisa
NL: TNO, NXP Semiconductors, Technische Universiteit Eindhoven
+ other partners from **ES**, **UK**, **RO**, **AT**, **LV**, **LT**, **FI**, **FR**, **CZ** and **Taiwan**

Total budget
€ 53.7 m.

EC Contribution
€ 17.3 m.

Contract Number
662192

Components for Complexity Control in affordable electrified CARs

Electric cars represent one of the most enhanced applications of the most recent technological innovations. Despite all the benefits, complexity and cost have also risen and their success has been limited. 3Ccar focuses on making car components simpler, more robust and affordable, spanning the entire technology from battery cells to motors.

Objectives

The 3Ccar project provides highly integrated Components for Complexity Control in thereby affordable electrified cars. New semiconductors for complexity management (through its control and reduction) offer the next level of energy efficiency in transportation systems. 3Ccar's impact is to maximize pragmatic strategy, i.e. use semiconductor technology-based innovations to manage functionality and increased complexity. This leads to cheaper, more efficient, robust, comfortable, reliable and usable automotive systems, strengthens Europe as a whole (OEM, Tier1, Semiconductor) by generating economic growth and new jobs. 3Ccar's impact is driven vertically by innovations and horizontally by promoting growth and deployment in industry based on perceived European values. European engineers are recognized as developers, who ensure highest efficiency, convergence and manageable complexity. Our society values long-life products since they curtail waste. Fifty partners and a 55 M€ budget offer the overwhelming majority for innovative products, such as functional integrated powertrains and smart battery cells, unique selling features that enable Europe to advance towards global leadership. An important feature of the project has been to recognize and exploit synergies with other EU projects to allow rapid innovation cycles between aligned projects. The 55 M€ budget and 10 B€ impact generate an R&D expenditure ratio of 200, which is ten times higher than the semiconductor average and represents very strong innovation potential for transfer to the car and semiconductor industries. The technologies developed in the 3Ccar project are intended for worldwide commercialization, while promoting European OEMs wishing to manufacture in Europe. 3Ccar involves the standardization needed to ensure the setting up of large vertical supply chains. 3Ccar proves that cooperation between industry, research institutes, governments and customers is pivotal to excellence in Europe.

CEA-Leti in 3Ccar

The main aim of the 3Ccar project is to establish a cooperative environment among almost fifty European research teams with shared visions and objectives. Such a large project is naturally divided into ten subprojects, each addressing a specific subject. Thus, three teams from CEA, CEA-Liten and CEA-Leti have been working on the following three topics:

• The aim of the Smart Battery Cell activity is to build a 48V battery module demonstrator using Smart Li-ion Cells with embedded electronics to measure cell properties, ensure safe operation and communicate with the external BMS. A CEA-Liten team has designed the best architecture and algorithms for embedded Electrochemical Impedance Spectroscopy (EIS), which provides an image of the internal cell condition

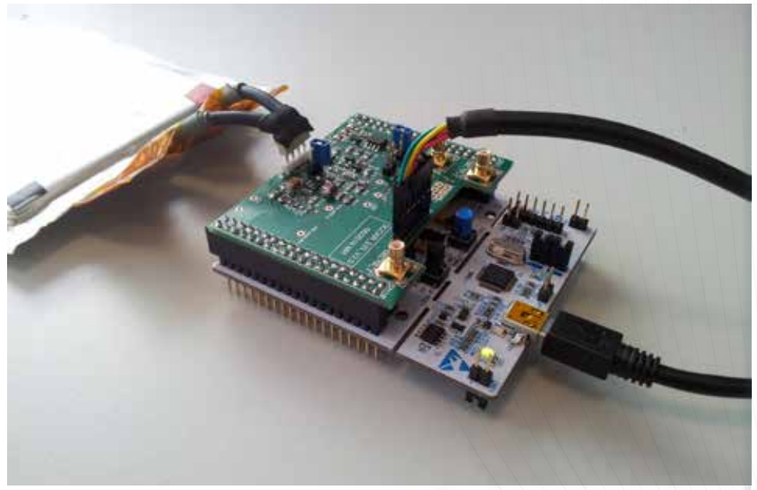
• The entire vehicle powertrain falls within the scope of the Integrated Powertrain activity. CEA-Liten and CEA-Leti engineers have designed and simulated an electric motor with a built-in power controller based on GaN transistor technology

• The Smart Semiconductors for Fuel Cell activity has addressed all the elements and devices composing a Smart Fuel Cell system. In this connection, a CEA-Liten team has developed a prototype of a DC/DC liquid cooled power converter with characteristics suitable for range extender applications and a 10-15 kW power output.

Outcomes:
• A full Smart Battery Module has been assembled in cooperation with the partners.

• Results of design and simulation work for an electric motor powered by a GaN-based inverter have been encouraging. GaN technology is expected to soon replace SiC transistors, which are very expensive to produce. Simulation has proved that GaN is an affordable, reliable alternative.

• A DCDC power converter, designed to be integrated into the top of a standard fuel cell, has been fully developed, tested at different electrical loads and given satisfactory results in terms of efficiency, output voltage stability and input current ripple.



Embedded electronics by CEA-Liten for the electrochemical impedance estimation of a Li-ion cell.
© CEA-Leti

IMPACT

CEA research teams at CEA-Liten and CEA-Leti institutes have acquired additional knowledge in the development of e-motors and inverters. This has prompted take-up of new projects involving e-vehicles, in which CEA is designing and developing a new generation of GaN-based inverters in cooperation with industrial partners. The 3Ccar project has led to new cooperative research at European level ranging from battery-powered mobility to new e-vehicles.

Publications

«Electronic Module for the Thermal Monitoring of a Li-ion Battery Cell through the Electrochemical Impedance Estimation», M. Ranieri, D. Alberto, H. Piret, V. Cattin, Therminic 2016 Conference, Budapest (Hungary), September 2016.
The presented poster was awarded with the 'Best Poster Award'.
FULL TEXT LINK: https://www.researchgate.net/publication/308470908_Electronic_Module_for_the_Thermal_Monitoring_of_a_Li-ion_Battery_Cell_through_the_Electrochemical_Impedance_Estimation

TRL
1 **2** **3** **4** 5 6 7 8 9

Marco Ranieri
marco.ranieri@cea.fr

Bernard Strée
bernard.stree@cea.fr



5E

eeeee

www.linkedin.com/in/5e-h2020project

Keywords
Electronics industry
Electronics smart systems
European Electronics sector
Flexible and wearable electronics
Nanoelectronics
Roadmap

5E at a glance

30 months
Jan. 2019 > Jun. 2021

EC Programme
H2020 ICT-07-2018
Coordination and support action

Project Coordinator
VDI/VDE (DE)

Partners
DE: HSG
FR: CEA, Euripides
IT: MESAP
NL: HOLST-IMEC, HOLST-TNO

Total budget
€ 1.0 m.

EC Contribution
€ 0.15 m.

Contract Number
825113

Federating European Electronics Ecosystems for Competitive Electronics Industries

5E is a coordination and support project to federate European electronics ecosystems. It aims to describe and federate three European electronics sectors, namely nanoelectronics, flexible and wearable electronics, and electronic smart systems.

Objectives

European decision makers acknowledge the challenges that the electronics industry faces within a context of fierce global competition. Launching large-scale investments and supporting actions, including ECSEL, PENTA and IPCEI, for driving innovation are an important step towards strengthening this key economic sector. Europe needs long-term visions and strategies for its entire electronics industry in order to maintain a competitive edge and foster value creation. Revision of the EC electronics strategy represents a major ongoing contribution and this will be taken into account in the project. Simultaneously, industrial and societal digitization is a megatrend that urgently requires electronics for the hardware building blocks that complement and interact with other areas such as software, communications, computing, robotics and photonics.

The 5E project is underpinning digitization and is specifically supporting the electronics industry in seizing opportunities by federating (not merging) the three European electronics ecosystems. This will be achieved by developing a joint vision based on the state of the art and by focusing on interfaces and opportunities for collaboration and cross-fertilization. A technology and application meta-roadmap has been drawn up and implemented in the three electronics areas as well as in application sectors, digitization areas and on both European and regional policy levels. Dedicated actions are planned to reinforce cooperation and outreach across Europe - in all relevant value chains, sectors, areas and target groups – and at the international level. Targeted actions are reaching out to EU projects, major industry, SMEs, start-ups, demand-side users and the wider public; they include a toolbox, digital library and showcase as well as a contest. Seven influential partners with deep technological and methodological expertise have joined forces and are supported by 37 associate partners (industry, demand-side, digitization, and regions).

CEA-Leti in 5E

CEA-Leti's main contribution to the 5E project involves supervising the joint vision of the three electronics areas by:

- Describing a unified landscape for the three electronics areas and their interfaces (nanoelectronics, flexible and wearable electronics and electronic smart systems)
- Identifying white spots at these interfaces
- Developing a joint vision for competitive electronics industries in Europe.

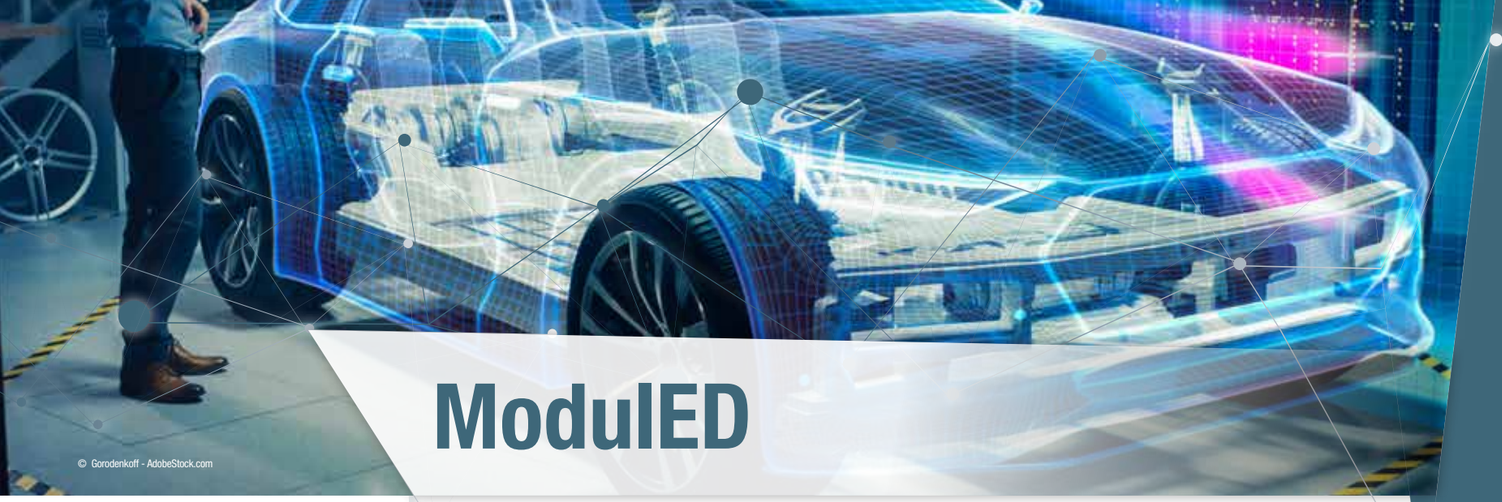
IMPACT

On the European scale, the 5E project is creating and developing a broad-based community and network of research partners to generate new research ideas and innovation.

A common roadmap for European electronics sectors is also being drawn up.

Elise Saoutieff
elise.saoutieff@cea.fr

Bernard Stree
bernard.stree@cea.fr



ModulED

Objectives

Electrification of passenger cars and light-duty vehicles will have a knock-on effect on reducing greenhouse gas emission from the transport sector, which remains the highest emitter due to fossil fuel-powered engines. However, the maturity of electrical drives and electrical engines needs a final push to achieve better performance, comfort and lower cost to prompt mass adoption of electric vehicles in Europe and beyond. ModulED is aimed at developing a new generation of modular electric engine based around a buried-permanent magnet motor with limited use of rare earth metals and an electric drivetrain for various configurations of Full and Hybrid Electric Vehicles (taking into account cost, environmental impact, efficiency and mass production readiness). The multiphase e-motor will integrate the latest GaN inverter for power electronics, advanced control with higher fault tolerance and advanced cooling features based on reduced sizing and higher efficiency. It will be coupled with a performance electrical drive and transmission adapting new regenerative braking strategies. The project takes into account industrial and user requirements as well as environmental impacts, through life cycle analysis, to gear activities towards full vehicle design and production of each component and the entire powertrain. New virtual models will be developed for reliable design and simulation of all component features. Demonstration on a BMW i3 or similar vehicle will be performed on project completion to validate the high-performance powertrain. ModulED associates nine cutting edge partners from automotive, power electronics and powertrain specialists with three research centers, three Tier-1 suppliers and SMEs.

ModuED

www.moduled-project.eu

Keywords
All integrated
Electronic gearbox
Gallium Nitride semiconductor (GaN)
High speed multiphase motor

Modular Electric Drivetrains

The ModulED project is researching and building a new powertrain for 3rd generation electric vehicles based on mass production and lower cost requirements.

InDeal at a glance

36 months
Oct. 2017 > Sept. 2020

EC Programme
H2020-GV-04-2017
Next generation electric drivetrains for fully electric vehicles, focusing on high efficiency and low cost

Project Coordinator
CEA-Leti (FR)

Partners
BE: Punch Powertrain
DE: RWTH Aachen University, ZG GmbH
FR: Efficient Innovation, Siemens Industry Software
NL: Technische Universiteit Eindhoven
SE: Chalmers Tekniska Hoegskola
SW: Brusa Elektronik

Total budget
€ 7.2 m.

EC Contribution
€ 7.2 m.

Contract Number
769953

CEA-Leti in ModulED

CEA-Leti is coordinator of the ModulED project.

• CEA-Leti is involved in developing the power electronics for ModulED along with a >100 kW, gallium nitride (GaN) semiconductor-based inverter for automotive applications dedicated to a new generation of multiphase high-speed motors (up to 22,500 rpm). Using GaN devices reduces the inverter volume and increases its efficiency due to low on-state resistance and unrivalled switching performance.

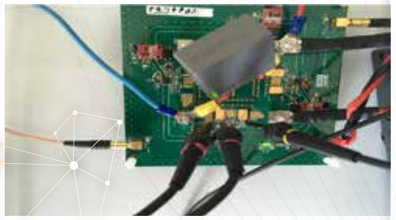
• CEA-Leti is working on parallelization of discrete components to increase the current capability of the GaN inverter (up to 4 parallel discrete devices achieved). This increased current capacity will increase torque and hence vehicle acceleration. The Institute has successfully performed parallelization for 2 discrete devices (tested at 300 V, 90 A). It has also performed parallelization with 4 discrete devices (up to 200 V / 60 A) and is continuing work on this configuration.

• CEA-Leti is addressing mechanical integration inside the motor housing to ensure optimum system compactness (motor + transmission + gearbox + inverter + cooling). To achieve this, the Institute is cooperating closely with a European partner for integration of the power electronics as close as possible to the motor (inside the housing) along with the related fluid cooling system.

• CEA-Leti is also involved in the local control and communication interface between the power part, the control part and the driver. This interface, also located within the motor housing, is designed to detect failures, high temperatures, bad commands and system switching to safety mode. The main objectives are to first protect the driver in the car and then protect the mechanical, electrical and magnetic equipment in the system.



Picture of the powertrain built during the project.
© CEA-Leti





Test for GaN devices in parallel.
© CEA-Leti

IMPACT

The GaN inverter will be the world's first to be integrated into an automotive application and into a motor housing. The ModulED project will demonstrate the relevance of GaN technology for automotive applications and the reality of its challenge to SiC technology (same breakdown voltage, 650 V and lower voltage), which is mature and currently used by industry.

Publications
«DC-Bus capacitors influence in a GaN Motor Drive Inverter PCIM», C. Lanneluc, P. Perichon, D. Bergogne, Nuremberg 13th-16th of May, 2019.

TRL
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Charley Lanneluc
charley.lanneluc@cea.fr

Bernard Strée
bernard.stree@cea.fr



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NENUFAR

Next gEneration of eNergy storagE solUtions
For more electricAl aiRcrafts

The aim of the NENUFAR project is to produce a complete, innovative, battery system designed to reduce weight, increase power density and ensure a high safety level for aeronautic applications. The system architecture integrates a Li-Ion battery coupled with a battery charger and a battery controller to ensure optimum energy usage. The Li-Ion battery and charger design focuses on technologies enabling a major reduction in overall system weight. This project is conducted by different European entities including CEA-Liten, Friedrich-Alexander University, CEA-Leti, Arkema, TTTech and with the close cooperation end-user TAES.

Keywords
Battery
BMS
Charger
Converter
Electrical architecture
High voltage
Li-Ion
Low voltage
Safety

NENUFAR at a glance

48 months
Jan. 2018 > Jan. 2022

EC Programme
H2020-CS2-CPW04-2016-01 Clean Sky

Project Coordinator
CEA-Liten (FR)

Partners
AT: TTTech
DE: Friedrich-Alexander Univerisity
FR: Arkema, CEA-Leti, CEA-Liten, Thales

Total budget
€ 5.3 m.

EC Contribution
€ 4.9 m.

Contract Number
807081-CSJU-CS2-SYS-GAM-2018

Objectives

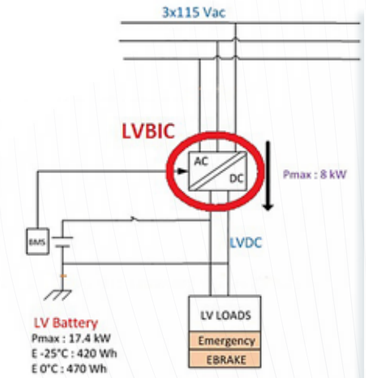
The combined challenges facing European aviation due to continuous traffic growth, rising fuel costs, stricter emission and noise targets set by the FlightPath 2050 goals and ever greater global competition require development of new breakthrough technologies.
The specific challenge of building more efficient, cost effective green aircraft by the year 2050 highlights the need for break-through innovations to support the transition from existing fuel-based energy sources, including hydraulic and pneumatic, to electrification, while increasing availability, reliability and maintainability. However, despite the stakeholders' strong desire to build the electrical plane, the community remains conscious of the major electrical aviation challenges, specifically:
• Energy storage capacity. The increase in power consumption due to expanding airline customer needs has resulted in a major problem: current equipment systems that supply, generate, distribute, transmit and consume power result in inefficient use of on-board power
• Weight reduction. Electrical energy technologies are often heavier than conventional solutions, which perpetualized weight reduction in this sector
• Safety level. Reliability and safety levels are very high in aeronautics compared with other sectors. Safety is a dominant criterion in choosing a technical solution and this makes reliability and safety two fundamental research issues.

CEA-Leti in NENUFAR

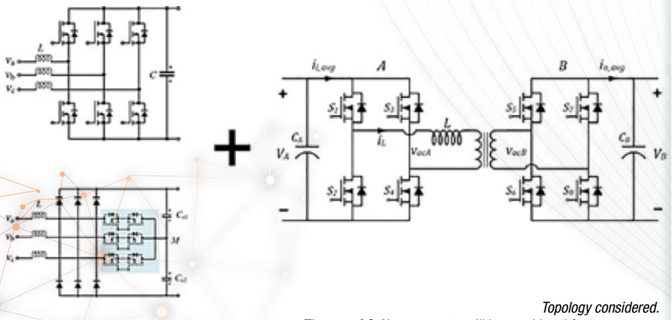
The original project program was to develop an isolated bidirectional charger that couples the LV battery and LVDC bus.
The system architecture defined in 2018 (defined in 2018) now requires development of a unidirectional isolated converter that couples the LV battery and LV bus with the aircraft's 3-phase AC main supply. This AC/DC converter is called the LV converter.

Work achieved
In the main, 2018 was used to define the system architecture with CEA-Leti's contribution being the final choice.
In parallel, CEA-Leti drafted the specification for the LV converter specification, which was delivered in December 2018. Its architecture, shown in Figure 3, is based on a 2-stage topology.
In 2019, CEA-Leti designed the LV converter's first RUN for first mock-up early in 2020.

This included:
• A theoretical study to define the right topology
• design and the fabrication of the LV converter
• First tests of the converter to provide inputs for the second RUN leading to the prototype.



System architecture of the battery system.
© CEA-Leti



Topology considered.
The use of GaN components will be considered for two reasons:
• voltage withstanding of the devices versus performances;
• higher switching frequency reachable allowing better power density System architecture of the battery system.
© CEA-Leti

IMPACT

The aim of the NENUFAR project was to optimize battery system architecture in terms of performance and safety for the next generation of aircraft using Li-Ion batteries. This was achieved thanks to close cooperation with TAES spanning specifications to final prototype through ensuring key choices such as overall electrical architecture, battery technology and converter topology. On the CEA-Leti side, the converter allows us to merge the battery charger and the LV bus power supply into a single converter. This has a major impact on the power density of the complete system.

Publications
• «Energy Storage: Lithium-Ion battery for aircraft applications», M. Pontrucher (1), A. Villain (1), R. Casimir (1), J. Devautour (1), L. Garnier (2), D. Chatroux (2), S. Fiette (2), R. Vincent (2).

1 : Thales Avionics Electrical Systems, 41, boulevard de la République 78401 Chatou, France.
2 : Univ. Grenoble Alpes, CEA, Liten, DEHT F-38054 Grenoble, France.

MEA (More Electrical Aircraft) 2019, 6th and 7th of February.

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Sébastien Carcouët
sebastien.carcouet@cea.fr

Laurent Garnier
laurent.garnier@cea.fr

Bernard Strée
bernard.stree@cea.fr

WIRELESS SYSTEMS & NETWORKS

3D-Muse
5G-ALLSTAR
5G-CARMEN
5G CHAMPION
5G Conni
5G-GaN2
5G-Heart
5G MiEdge
5G MoNArch
Clear5G
EnABLES
EnSO
FED4SAE
HIGHTS
INSIGHT
INSPEX
SECREDAS
SPEED5G
TOPAs
Wise-IoT

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3D-Muse

Objectives

The Internet of Things (IoT) is composed of connected devices that are characterized by their interaction with the environment via a plethora of sensors and actuators. The trend is towards ever more complex interactions and therefore more sensors of different types integrated into the same product, which requires, in turn, the processing capability to handle all the sensors.
At the same time, these systems are expected to continue performing at an ever lower power budget, preferably as low as to be able to operate purely from power scavenging. The cost also needs to be moderate. The electronics at the heart of such a system needs to be mixed-signal electronics interfacing with analog sensors and actuators but it must also supply the necessary digital processing power.
3D-MUSE is spearheading the progression from what we refer to as 'systems-in-stack' to true 'systems-incube' enabled by monolithic/sequential 3D integration. The former is defined as a 3D system characterized by locating functional blocks within a single plain in the (typically parallel/wafer-bonding) 3D integration stack, while the latter offer freedom of interconnect density in the third dimension of sequential 3D integration by implementing functional blocks in a volume of multiple tiers. We have demonstrated this concept by designing novel architectures for micro-circuits in a volume using a two tier, 3D sequential integration process. We have identified mixed-signal circuits as a major bottleneck in functional performance scaling of sensor nodes and smart sensors in IoT and cyberphysical systems. But they are also excellent candidates for beneficial trade-offs, when implemented as circuits in a volume by using two specialize tiers, one for analog device options and the other for optimal digital designs. We refer to such a technology as 'multiprocess' sequential 3D integration.

3D-MUSE

www.3dmuse.eu

Keywords
Components
Electrical and electronic engineering
Mixed-signal
Semiconductors
Sensor interfaces
Sequential 3D integration
Smart imagers
Smart sensor nodes
Systems

3D Multi-Process Sequential Integration for Smart Sensor Interfaces

The 3D-MUSE project embraces research and development of smart sensor interfaces using 3D sequential technology. This allows 2 layers of electronic devices to be stacked and «systems-in-cube» to be built based on digital/analog, fine-grained partitioning using a very high 3D interconnect density.

3D-Muse at a glance

48 months
Jan. 2018 > Dec. 2021

EC Programme
H2020-ICT-2017-1
ICT-31-2017 Micro- and-nanoelectronics technologies

Project Coordinator
University of Oslo (NO)

Partners
FR: CEA-Leti, Institut Polytechnique de Grenoble, STMicroelectronics
NO: Integrated Dectector Electronics AS (IDEAS), University of Oslo
SE: Lund University

Total budget
€ 3.8 m.

EC Contribution
€ 3.8 m.

Contract Number
780548

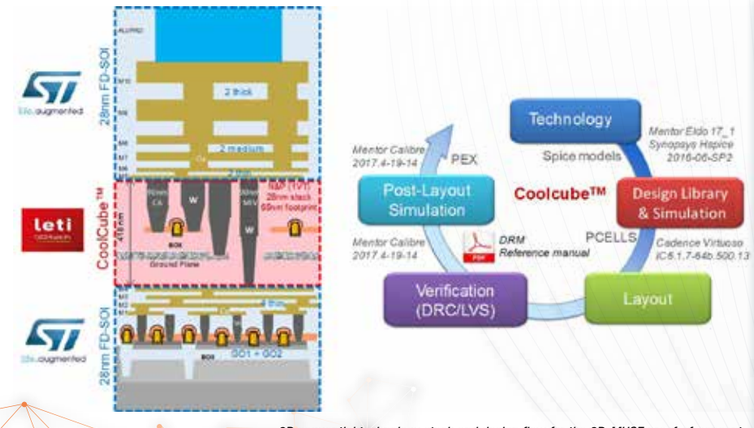
CEA-Leti in 3D-Muse

During the first two years of the 3D-MUSE project, 2 prime contributions have been made in the fields of 3D sequential technology and Process Design Kit (PDK) development.

The milestone in process integration is validation of analog layer stability. This means that CEA-Leti CoolCube™ technology is now compatible with analog or digital partitioning and MOS analog device specification is achieved.

The milestone in PDK development is availability of a complete Electronic Design Automation (EDA) environment for designing proof-of-concept technological and application test vehicles. This environment has been deployed across all our partners involved in the test chip design.

The attached figure shows the 3D sequential technology stack and the design environment for the 3D-MUSE proof of concept.



3D sequential technology stack and design flow for the 3D-MUSE proof-of-concept.
© CEA-Leti

IMPACT

Multiple actions have been undertaken to dessiminate and promote 3D sequential (CoolCube™) technology developed by CEA-Leti; a number of keystone publications are listed below. CEA-Leti has take, part in several conferences and workshops and has published technical and survey articles. Several world leaders in the semiconductor field (IDM, fabless, EDA vendors, etc.) have been contacted.

Publications

- *«A Review on Opportunites Brought by 3D-Monolithic Integration for CMOS Device and Digital Circuit», F. Andrieu, P. Batude, L. Brunet, C. Fenouillet-Béranger, R. Berthelon, D. Lattard, S. Thuries, O. Billoint and M. Vinet, ICICDT'2018, Otranto, Italy, June 2018.*
- *«3DVLSI, Technology and Application» S. Chéramy, A. Jouve, C. Fenouillet-Beranger, P. Batude, M. Vinet, S3S'2018, San Fransisco, USA, Oct. 2018.*
- *«3DVLSI CoolCube™ MPW & design roadmap», S. Thuriès, O. Billoint, A. Makosiej, P. Vivet, E. Beigné, S. Choisnet, F. Andrieu, C. Fenouillet-Beranger, L. Brunet, P. Batude, D. Lattard, M. Mouhdach, S. Martinie, J. Lacord, G. Cibrario, S. Cheramy, M. Vinet, F. Clermidy, J.- E. Michallet, J.- R. Lequepeys, S3S'2018 – 3DVLSI Open Workshop, San Fransisco, USA, Oct. 2018.*
- *"«Monolithic 3D : an alternative to advanced CMOS scaling, technology perspectives and associated design methodology challenges», P. Vivet, S. Thuriès, O. Billoint, S. Choisnet, D. Lattard, E. Beigné, P. Batude, ICECS'2018, Bordeaux, France, Dec. 2018.*
- *«Breakthroughs in 3D Sequential technology», L. Brunet, C. Fenouillet-Beranger, P. Batude, S. Beaurepaire, F. Ponthenier, N. Rambal, V. Mazzocchi, J.-B. Pin, P. Acosta-Alba, S. Kerdiles, P. Besson, H. Fontaine, T. Lardin, F. Fournel, V. Larrey, F. Mazen, V. Balan, C. Morales, C. Guerin, V. Jousseaume, X. Federspiel, D. Ney, X. Garros, A. Roman, D. Scevola, P. Perreau, F. Kouemeni-Tchouake, L. Arnaud, C. Scibetta, S. Chevalliez, F. Aussenac, J. Aubin, S. Reboh, F. Andrieu, S. Maitrejean, M. Vinet, IEDM'2018, San Fransisco, USA, Dec. 2018.*

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Didier Lattard
didier.lattard@cea.fr

Yves Quéré
yves.quere@cea.fr



5G-ALLSTAR

5G Agile And Flexible Integration of Satellite and Cellular

The 5G-ALLSTAR project paves the way to 6G with 3D super connectivity. It demonstrates multiple access, combining cellular and satellite access technologies, to ensure high service availability, service continuity and network reliability over a wide area.

https://5g-allstar.eu

Keywords
5G
Cellular
Multi-radio access Technology
Network reliability
Satellite
Service continuity
Super connectivity

5G-ALLSTAR at a glance

36 months
Jul. 2018 > Jun. 2021

EC Programme
H2020-EUK-02-2018

Project Coordinator
CEA-Leti (FR)

Partners
DE: Fraunhofer
FR: CEA-Leti, EESC Grenoble Ecole de Management, Thales Alenia Space
IT: Consorzio per la Ricerca nell'Automatica e Telecomunicazioni
KR: Electronics and Telecommunications Research Institute, Korea Automotive Technology Institute, Korea Telecom Satellite, SK Telecom, Snet ICT

Total budget
€ 2.0 m.

EC Contribution
€ 2.0 m.

Contract Number
815323

Objectives

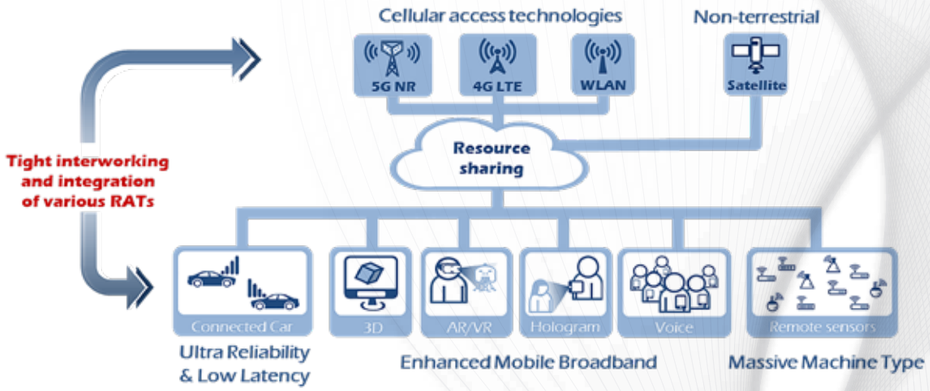
5G Communication Networks are today mature enough for developing key enabling technologies that allow for extended Proof of Concepts (PoC). Although standardization of 5G is yet to be finalized, 5G players have already reached general agreement on key enabling technologies, architecture and deployment scenarios for 5G networks. The 5G community is now looking to translate 5G use cases, vertical industry requirements and 5G adoption ambitions into viable business cases. However, support of 5G new services and seamless connectivity across various vertical industries and highly diverse use cases still requires integration of multiple access technologies. 5G-ALLSTAR builds on the outcomes and the cooperation experience of the 5GCHAMPION project to design, develop, evaluate and trial multi-connectivity based on multiple access, combining cellular and satellite access technologies to support seamless reliable and ubiquitous broadband services. The project aims to validate system interoperability, to provide global connectivity and support mission critical applications of interest in European and Korean regions. To this end, 5G-ALLSTAR is developing selected technologies and targeting a set of PoCs to validate and demonstrate in a heterogeneous real setup, i) a 5G cellular mmWave access system for broadband and low-latency 5G services, ii) new radio-based feasibility of satellite access for broadband and reliable 5G services, iii) multi-connectivity support based on cellular and satellite access, iv) spectrum sharing between cellular and satellite access. The project is also actively contributing to, v) global 5G standardization including 3GPP and ETSI, focusing on multi-RAT interoperability and New Radio-based satellite access, vi) creation of cross-regional lasting synergy for 5G research, innovation and commercialization through value proposal assessment for vertical industries.

CEA-Leti in 5G-ALLSTAR

In addition to ensuring 5G-ALLSTAR project coordination, CEA-Leti is:

• Investigating algorithms, which will be developed at the physical layer, for the terrestrial part of a 5G multi-access system. Their purpose is to mitigate the spectrum interference that occurs when several access systems share the same or adjacent bands. Interference may come from other terrestrial systems like 4G or WiFi or from satellite systems. The studies include not only time and frequency filtering as an option for decreasing out-of-band rejections, but also interference cancellation algorithms. The 5G NR physical layer (release 15), i.e. CP-OFDM (Cyclic Prefix Orthogonal Frequency Division Multiplexing), serves as a basis for the work

• Contributing to the Proof of Concept. The aim of the project is to ensure technology demonstration of the feasibility of mmWave-based 5G access networks capable of providing broadband and low-latency 5G services. Demonstration requires CEA-Leti to produce a **real-time FPGA (Field Programmable Gate Array)-based Layer 1 modem, operating in the millimeter wave band**, featuring an embedded light MAC (Medium Access Control) hosted on the ARM processor of the digital board. High speed Analog to Digital and Digital to Analog Converters will be used to transmit and receive in Intermediate Frequency for the tests with a channel emulator. Off-the-shelf Radio Frequency front-end and off-the-shelf antennas will be used for airborne transmission. This approach allows the previously designed layers to be evaluated under real conditions.



Overview of 5G multi-radio access.
© CEA-Leti



IMPACT

The 5G-ALLSTAR project positions Europe as a major player in 3GPP New Radio (5G) standardization via the inclusion of satellite connectivity in releases 16 and 17. Moreover, the project fosters close interaction between European and Asian ecosystems on 5G and beyond.

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Nicolas Cassiau
nicolas.cassiau@cea.fr

Bernard Strée
bernard.stree@cea.fr



5G-CARMEN

5G for Connected and Automated Road Mobility in the European unioN

Radio connectivity is key to higher levels of vehicle autonomy, while increasing safety and providing entertainment. Maintaining connectivity and automated mobility across borders is a challenge. The 5G CARMEN project will deploy 5G cells for extensive testing in the Bologna-Munich corridor.

5G CARMEN
www.5gcarmen.eu

Keywords
5G
Automotive
Autonomous cars
Connectivity
Corridor

5G-CARMEN at a glance

36 months
Nov. 2018 > Oct. 2021

EC Programme
H2020

Project Coordinator
Fondazione Bruno Kessler (IT)

Partners
AT: High Tech Marketing, T-Mobile Austria, Virtual Vehicle
BE: IMEC
CY: 8 Bells
DE: BMW Group, Deutsche Telekom, NEC, Nokia, Qualcomm
ES: Universitat Politecnica de Valencia
FR: CEA-Leti
GR: Wings
IT: Autostrada del Brennero, Centro Ricerche Fiat, Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), DriveSec, Infrastruttere WirelessItaliane, Libera Università di Bolzano, PIIU, Swarco, Telecom Italia
NL: Cyberlens

Total budget
€ 18.5 m.

EC Contribution
€ 14.9 m.

Contract Number
825012

Objectives

European mobility is changing in extraordinary ways: growing urbanization, environmental considerations and safety are just a few of the key indicators of current trends. Road infrastructures and vehicles are blending with the digital world, becoming always-connected, automated and intelligent, delivering optimum experiences to passengers, addressing societal goals (emission and accident reduction) and economic needs (vehicles as smart-living environments). In this respect, the European Union is pushing for large-scale collaborative cross-border validation activities involving cooperative, connected and automated mobility. 5G CARMEN addresses these challenges by harnessing the concept of "Mobility Corridors". Key European industries, academics and innovative SMEs are committing to a world-wide impact by conducting extensive trials on a major corridor (measured by people/goods traffic volume) from Bologna to Munich, which embraces 600 km of roads connecting three European regions (Bavaria, Tirol and Trentino/South-Tyrol) across three countries. Vehicle maneuver negotiation (at various levels of automation), infotainment and emission control in sensitive areas are the cross-border use cases targeted by 5G-CARMEN managers to maximize the project's commercial, societal and environmental impact.
The project aim is to build a 5G-enabled corridor for conducting cross-border trials with a mixture of 5G micro- and macro-cells deployed for ubiquitous C-V2X connectivity. The 5G New Radio supports latency sensitive and/or bandwidth hungry services and applications. The project leverages a distributed mobile edge cloud from the vehicle itself to the centralized cloud. Multi-tenancy and neutral host concepts are implemented to deliver a final platform capable of enabling new business models. 5G-CARMEN uses C-V2X, complemented by LTE and C-ITS technologies, for targeting interoperability and harnessing a hybrid network.

CEA-Leti in 5G-CARMEN

Connected mobility can be envisaged in two ways.

Firstly, each vehicle estimates its own position/speed/acceleration, heading, etc. from raw GPS data, an inertial unit, an odometer/wheel speed counter, etc. It is assumed that the vehicle estimates error statistics characterizing the uncertainty associated with this information. Positional data and related error statistics are then transmitted via V2X (possibly over multiple hops) at regular intervals or in an event-driven way. The goal is to find the best compromise between:

• Transmitted data size/rate, data availability/latency, coverage/depth of cooperation (e.g. number of hops)

• Confidence in neighbors' predicted trajectories.

More data and/or more frequent transmissions imply more accurate trajectory/intention predictions on the time horizon but also more transmission errors due to increased channel load.

Secondly, each vehicle elaborates and updates a local car-centric map of its physical environment, e.g. a Lidar-based occupancy map (with positions of not only neighboring vehicles, but also passive obstacles). Using V2X, the maps are shared so that each vehicle receives maps (possibly in a compressed form) from neighboring vehicles and/or from fixed infrastructural elements. Finally, each vehicle can merge the received information (using a state-of-the-art data fusion algorithm) to obtain a refined local map that goes beyond its immediate physical sensing capabilities (in terms of coverage), while increasing its resolution/reliability. As in the previous case, the quantity of exchanged data, their refreshment rate and the size of the covered zone impact on the quality of the map to be assessed.

CEA-Leti's goal is to use its simulation tools (automotive traffic simulator and radio V2X simulator including realistic propagation models) to evaluate these two approaches in scenarios such as "changing lane" on a highway.



IMPACT

Development of connected cars and autonomous driving is one of Europe principal ambitions. CEA-Leti's wishes to contribute to its success by defining innovative cooperation schemes between vehicles and infrastructure via exchanges of information such as awareness data and/or vehicle environment maps.

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Benoît Denis
benoit.denis@cea.fr

Bernard Strée
bernard.stree@cea.fr



5G CHAMPION

http://www.5g-champion.eu/

Keywords
5G
Backhauling
Core network
Millimeter wave technologies
Mobility
Satellite positioning
and communications

5G CHAMPION at a glance

24 months
Jun. 2016 > May 2018

EC Programme
H2020-ICT-EUK-01-2016

Project Coordinator
CEA-Leti (FR)

Partners
BE: IMEC
DE: Fraunhofer Heinrich Hertz Institute, Intel
FI: University of Oulu, Nokia
FR: CEA-Leti, Thales Alenia Space, Telespazio
KR: Clever Logic, Dankook University, Eluon, ETRI, Gwangju Institute of Science and Technology, Hanyang University, HFR, InSoft, Korea Telecom, Mobigen, Seoul Metropolitan Rapid Transit, Seoul National University, South Korea Telecom

Total budget
€ 3.0 m.

EC Contribution
€ 3.0 m.

Contract Number
723247

5G Communication with a Heterogeneous, Agile Mobile Network in the PyeongChang Winter Olympic Competition

The 5GCHAMPION project was launched in June 2016 as one of three first projects within the cooperation framework between MIST (Korean Ministry of Science) and the European Commission. Its ambition was to develop key enabling technologies for a proof-of-concept environment to be showcased at the 2018 Winter Olympics in PyeongChang, Korea.

Objectives

The 5GCHAMPION project ensured maximum visibility for available technology two years ahead of 2020, the year of 5G's official launching. 5GCHAMPION provided an efficient Korean/European cooperation framework, established new research and business relationships among consortium partners and guaranteed continued cross-fertilization and thought leadership after the project lifetime. Its success was strategic for Korea and Europe in terms of maximizing impact through a common Korean/European position. Joint forces would introduce the novel technologies to global standards and regulation bodies, such as 3GPP, ETSI, IEFT, ITU, etc., to thereby maximize impact through a common Korean/European position. Technical key contributions included, i) a complex 5G set-up operating inside and close to the PyeongChang Olympic venue, which addressed indoor and outdoor propagation channels in mmWave and below in the 6GHz spectrum, ii) high-speed broadband connection via mmWave high capacity backhaul in the 24-28 GHz spectrum using novel antenna arrays for wireless back/front-hauling, enabling >2Gbps, iii) advanced evolved packet core solutions for efficient system management with virtualization through NFV/SDN in a secure backhaul architecture as well as novel SDN-based IPsec tunnel architecture, iv) novel accurate positioning solutions (<1m accuracy) using mmWave combined with GNSS PPP, v) direct UL/DL communication between satellites and 5G User Equipment 'as is' and establishment of a corresponding first proof of concept, vi) improved mobility support through a novel small cell architecture and hybrid adaptive beamforming. The overall project goal was to achieve a highly energy efficient system approach: a key requirement and challenge for 5G.

CEA-Leti in 5G CHAMPION

CEA-Leti was the project coordinator. In addition to management, dissemination and communication activities, the Institute's contributions focused on **designing electronically steerable antennas and implementing algorithms for high capacity mmWave backhauling/fronthauling**. CEA-Leti was also involved in defining and implementing the test bed dedicated to an NB-IoT over satellite channel, including PHY layer definition, testing and validation using a channel emulator.

CEA-Leti developed electronically reconfigurable Transmitarray antennas for backhauling and fronthauling at 28 GHz and designed RF impairment compensation algorithms resistant to high order modulation. It also investigated solutions for jointly using high order modulation and spatial multiplexing and for signal transmission in highly time-variant channels. Finally, it investigated advanced mobility management solutions based on the C/U plane split.

CEA-Leti proposed and compared various waveform candidates for meeting the requirements of 5G NB-IoT, such as critical applications. Waveforms in existing or coming standards under the 3GPP framework were considered (e.g. LTE category-M, LORA, Sigfox, NB-IoT). The 5G-like waveform (e.g. filtered multicarrier) was adapted to the specific requirements of low cost, low power consumption and satellite constraints (RF characteristic/performance, satellite channel characteristics). CEA-Leti investigated enhanced waveforms to lower PAPR as much as possible, while maintaining reasonable complexity on the transmitter side. New or improved waveforms were proposed on the basis of this.

CEA-Leti took part in integrating the 5G CHAMPION proof of concept for the backhauling solution. It implemented the specified experimentation satellite access test bed using an existing flexible hardware platform (dedicated hardware design with possible hardware in-the-loop component) and its in-house channel emulator. Finally, it took part in validation and the demonstration activities.



5G CHAMPION team.
© 5G CHAMPION

IMPACT

The major contribution of the 5GCHAMPION project was to prove the concept of a full 5G test bed including indoor and outdoor backhaul links and a core network. This PoC was demonstrated in Gangneung on February 20 - 22, 2018. Its technical results have been published and presented in over 37 accepted conference contributions and 13 accepted journal papers. A special issue of the ETRI journal was published, more than 40 press releases were issued and a 5G workshop was held in Seoul.

Publications

• "Where, when, and how mmWave is used in 5G and beyond», K. Sakaguchi, T. Haustein, S. Barbarossa, E. Calvanese Strinati, A. Clemente, G. Destino, A. Parssinen, I. Kim, H. Chung, J. Kim, I. W. Keusgen, R. J. Weiler, K. Takinami, E. Ceci, A. Sadri, L. Xian, A. Maltsev, G. Khanh Tran, H. Ogawa, K. Mahler, and R. W. Heath Jr., IEICE Trans. Electronics, vol. E100.C, no. 10, pp. 790-808, Oct. 2017, (Invited paper).
• «5G CHAMPION – Disruptive 5G Technologies for Roll-Out in 2018», E. Calvanese Strinati, M. Mueck, I. Kim, A. Clemente, J. Kim, G. Noh, H. Chung, T. Choi, G. Destino, A. Parssinen, N. Chuberre, B. Vautherin, and A. Korvala, ETRI Journal, vol. 40, no. 1, Feb. 2018.
• First intercontinental 5G trial begins at winter Olympics: the 5G Champion project shows off a 5G link between South Korea and Finland, IEEE Spectrum, 21 Feb. 2018.

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Emilio Calvanese Strinati
emilio.calvanese-strinati@cea.fr

Bernard Strée
bernard.stree@cea.fr



5G Conni

5G for CONnectec Industries

The 5G-CONNI project is investigating and demonstrating how 5G can enhance industry by creating Smart Factories, in which private 5G networks can be deployed. Network and cloud technologies are being developed and showcased through a multi-site testbed. Parallel private network deployment strategies and new business models are being investigated.

Keywords
5G
Industry 4.0
URLLC

5G Conni at a glance

36 months
Oct. 2019 > Oct. 2022

EC Programme
H2020-ICT-23 (joint EU-TW)

Project Coordinator
Fraunhofer HHI (DE)

Partners
DE: Bosch, Fraunhofer HHI
FR: CEA-Leti
IT: Athonet, La Sapienza (University of Rome)
TW: ITRI (Coordinator), Alpha Networks Inc., Chunghwa Telecom, III

Total budget
€ 4.1 m.

EC Contribution
€ 2.1 m.

Contract Number
861459

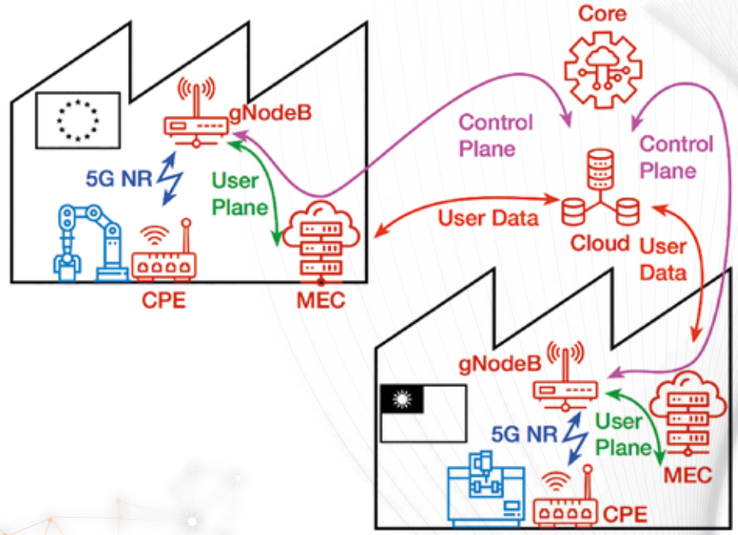
Objectives

The fifth generation of mobile communication networks (5G) is foreseen as key enabling technology for the industrial revolution's fourth stage, commonly called "Industry 4.0". Future Smart Factories envisaged in this context will leverage Industry 4.0 and 5G technology to increase flexibility and efficiency of manufacturing processes, thereby ensuring global competitiveness of industrial manufacturing. While 5G technologies, such as network slicing, may accommodate industrial applications in public networks, Private 5G Networks, operating locally and highly optimized towards specific applications, are a disruptive emerging approach to meeting the specific demands of industrial use cases. Building on the premise of Private 5G Networks, the 5G-CONNI project aims to provide an integrated end-to-end 5G test and demonstration network for industrial applications, leveraging current results from standardization and related research projects. Major contributions of the project consist in defining new Private 5G Network architectures and operator models, measurements and tools for application specific network planning, tuning, monitoring and developing innovative technologies and enabling components in the context of URLLC radio communication, mobile edge computing, core network design and joint optimization of these components. Two interconnected industrial trial sites at manufacturing facilities in Europe and Taiwan are being set up. Selected use cases will be tested at these sites and integrated into an end-to-end industrial Private 5G Network demonstrator. This will be used for technology verification and in-depth KPI analysis. The project results will be fed back to the relevant standardization bodies and industry forums, and used as input for the use of regulatory institutions in Europe and Taiwan in shaping private network operating requirements.

CEA-Leti in 5G Conni

CEA-Leti's expected outcomes of the 5G-CONNI project are:

- Increased know-how in connectivity for the «Factories of the Future» (FoF)
- Definition of private 5G factory network requirements and evaluation methodology
- Design of lower layers of 5G to accommodate Ultra Reliability, Low Latency Communications (URLLC) for FoFs
- Joint optimization of VNF deployment and cloud resource allocation based on distributed AI mechanisms.



Two production facilities are each equipped with their own radio access (CPEs / gNodeB) and mobile edge compute (MEC) capacities ; interconnecting sites is made through wide area networks and cloud services.
© 5G-CONNI

IMPACT

The project was launched at the end of 2019. Its expected impacts are:
- Proving feasibility of private 5G networks, while defining new operator models and developing planning tools and edge cloud technologies for efficient deployments
- Contributing to understanding and transferring knowledge of how to plan, deploy, operate and maintain a private 5G network in a factory
- Demonstrating industrial applications in real-world 5G trial systems, potentially with global interconnectivity
- Contributing to triggering and facilitating rapid adoption of 5G-CONNI key concepts by industrial players
- Contributing to standards and regulations aiming at private industrial 5G for working towards harmonized spectrum and numbering regulation.

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Mickaël Maman
mickael.maman@cea.fr

Bernard Strée
bernard.stree@cea.fr



5G-GaN2

5G Base Stations GaN Components And Circuits For RF Transceivers -2

The 5G-GaN2 project is aimed at developing new industrial technologies to enable faster data transfers for 5G wireless networks by using higher operating frequencies. To achieve this, efforts have focused on material development (gallium nitride), packaging design (heat dissipation) and circuit design based around new architectures.

https://www.5ggan2.eu/

Keywords
5G
GaN
RF
System in Package

5G-GaN2 at a glance

36 months
Jun. 2018 > May 2021

EC Programme
ECSEL Research and Innovation Actions (RIA)

Project Coordinator
UMS (FR)

Partners
DE: Airbus - Tesat, Fraunhofer IAF, UMS GmbH, University of Erlangen, X-Fab Dresden
FR: III-V Lab, CEA-Leti, Thales Communications et Security, UMS France
IE: Benetel, University College Dublin
IT: MEC, University of Padova
LU: Molecular Plasma Group
NL: Sencio
SE: Ericsson A, SweGaN AB
SK: Slovak University of Technology in Bratislava

Total budget
€ 21.4 m.

EC Contribution
€ 6 m.

Contract Number
783374

Objectives

A new generation of communication infrastructures is currently being developed. Fifth generation (5G) communications technologies will provide internet access to a wide range of applications spanneing billions of low data rate sensors to high resolution video streaming. The 5G network is designed to scale across these different use cases and is expected to use different radio access technologies for each use case.

To support very high data rates, 5G is projected to use wide bandwidth spectrum allocation at mm-wave frequencies. The bandwidth provided at mm-wave frequencies (above 24 GHz) is more than 10 times as broad as that in the lower bands (sub 6 GHz). However, the move to mm-waves comes with a drawback, specifically increased path loss. This makes it extremely challenging to provide coverage at mm-wave frequencies.
A partial remedy is to use beamforming to direct radio energy to a specific user. In some deployment scenarios, beamforming is insufficient and output power must also be increased. A major challenge is to bring affordable, high-performance mm-wave active antenna arrays into production. At present, there is market demand for these systems but there is still a capability gap.
The main objectives of the "5G_GaN$_2$" project are to lower substantially cost and power consumption and to increase the output power of mm-wave active antenna systems. Advanced Gallium Nitride (GaN) technology has been retianed to achieve maximum output power and energy efficiency. High-volume, low-cost packaging and integration techniques developed for digital applications are being considered to achieve the cost and integration targets.

A number of application-driven demonstrators are planned for highlighting the capabilities of the developed technology. Their role is to guide the technology development towards maximum impact and take-up in the post-design phase. The consortium embraces the complete value chain including wafer suppliers, semiconductor fabrication and system integrators. Key universities and research institutes are guaranteeing academic excellence throughout the project.

CEA-Leti in 5G-GaN2

The first project contribution involves **demonstration of CMOS-compatible 200 mm GaN on Si** epitaxy and subsequent Ka band (26.5 to 40 GHz) **transistor processing:**

- **Epitaxy:** GaN epitaxy on HR (High Resistivity) silicon substrates has been **fine-tuned to reduce RF losses from 2.5 db/mm to 0.8 dB/mm**. This is sufficient for current transistor integration work, but further improvement (<0.4 dB/mm) is required to demonstrate high performance transistors
- **Ohmic contact brick:** high performance, innovative and CMOS-compatible, **ion-implanted ohmic contacts** have been demonstrated (0.06 Ohm.mm)
- **Transistor:** transistor and test structure have been designed and corresponding mask set ERIS, combining optical and e-beam lithography, has been completed. CMOS compatible Ka-band transistor process flow has been defined (**Au-free, lift-off free**).

The second project contribution involves a **System in Package (SiP)** solution for mm wave devices:

- **Advanced packaging solutions:** fan-out wafer level packaging (FOWLP) in chip first face down configuration has been selected for 5G base transceiver station (BTS) applications. This solution includes an innovative molding opening for thermal dissipation
- **Thermal simulation** for material and design optimization
- **SiP design** of the first demonstrator dedicated to 5G BTS @26-28 GHz
- **SiP building block development:** use of CEA-Leti's 200 mm clean room facility for the FOWLP solution and a subcontractor for molding compound removal by laser
- **Moisture protection barrier layer at wafer level:** work is ongoing to select the best coating material for withstanding 85°C / 85% RH for 1000h under bias
- **Design and simulation of highly linear 45nm RF SOI T/R switch for 39-GHz FEM SiP:** RF simulated performance of the switch approaches performance found in silicon state of the art with ~2 dB insertion loss, ~20 dB isolation and adequate matching in both TX and RX modes. The IP1dB is +32.5 dBm.



Ball inspection on a package backside.
© CEA-Leti

IMPACT

- Development of CMOS compatible technology on GaN/Si substrates will facilitate **transfer to partner XFAB** (GaN device foundry). Ion-implanted Ohmic contact is a promising alternative to the more complex technique used by the majority of stakeholders in this field.

- FOWLP technology, including a thermal management solution, will allow development of **low-cost**, high-performance **FEM components, circuits and SiPs for mm waves, 5G and SatCom applications** in the 28 GHz, 39 GHz and 80 GHz range of frequencies.

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Arnaud Garnier
arnaud.garnier@cea.fr

Yves Quéré
yves.quere@cea.fr



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5G-Heart

5G Health Aquaculture and Transport Validation Trials

The 5G-HEART project addresses 5G wireless communication and its evolution across different activity sectors such as health, transport and aquaculture. The overall objective is then to define and validate the cost efficient 5G converged network concepts that will an intelligent hub supported by multiple vertical industries.

Objectives

Healthcare, transport and food verticals are hugely important in Europe in terms of jobs, turnover (together exceeding € 3Trillion) and export trade. Moreover, they are vital from a social perspective in relation to better healthcare outcomes, safer transportation and safer, more sustainable, food production. 5G is important for these verticals in terms of improvements ensuring utility, efficient processes and safety for others.

5G-HEART (validation trials) focuses on these vital vertical use cases in healthcare, transport and aquaculture. In the health area, 5G-HEART will validate pillcams for automatic screening detection of colon cancer and vital sign patches with advanced geo-localization as well as 5G AR/VR paramedical services. In the transport area, 5G-HEART will validate autonomous/assisted/remote driving and vehicle data services. Regarding food, the project will focus on 5G-based transformation of aquaculture sector (worldwide importance for Norway, Greece and Ireland).

The infrastructure shared by these verticals will host important innovations: slicing as a service, resource orchestration in access/core and cloud/edge segments with live user environments. Novel applications and devices (e.g. underwater drones, car components, and healthcare devices) will be developed. On-site trials will be held at 5G-Vinni (Oslo, Norway), 5Genesis (Surrey, UK), 5G-EVE (Athens, Greece) and at Oulu (Finland) and Groningen (Netherlands). Their results will be integrated to create a powerful and sustainable platform, on which slice concurrency will be validated at scale.

The project consortium includes major vertical players, research/academic institutions and SMEs. The partners have proven know-how in 5G, vertical applications, standardization, business modelling, prototyping, trials and demonstrations.

5G-HEART KPI validation will ensure improved healthcare, public safety, farm management and business models in a 5G market to stimulate massive business opportunities within and beyond the project scope.



http://5gheart.org/

Keywords
5G verticals
Aquaculture
Healthcare
MEC
Network slicing
Transport

5G-Heart at a glance

36 months
Jun. 2019 > May 2022

EC Programme
H2020-ICT

Project Coordinator
VTT (FI)

Partners
EL: ACTA, Ericsson, Intracom, National Technical University of Athens, OTE, Skironis
FI: Polar, VTT
FR: CEA-Leti
IE: Marine Institute, Redzinc
NL: Dynniq, Philips Electronics, TNO
NO: Oslo Universitetssykehus, Sealab, Telenor
UK: Epitomical, Oxfordshire County Council, University of Surrey

Total budget
€ 14.3 m.

EC Contribution
€ 14.3 m.

Contract Number
857034

CEA-Leti in 5G-Heart

CEA is contributing to two use cases:

• Healthcare and Transport
The issue at stake is to localize people wearing an LPWA (Low Power Wide Area, such as LoRa, 4G or 5G Nb-IoT) tag (e.g. victims of cardiac arrest) and possibly defibrillators. The objective is to assess the robustness of this technique in non-line-of-sight situations in both indoor and outdoor conditions.

• Transport
The objective for CEA-Leti is to study cooperation between vehicles sharing local maps to obtain an extended view of the surroundings. The CEA-Leti will simulate and evaluate the trade-off between, for example vehicle position refreshment rates, map resolution and warning message latency under various operating conditions (e.g. car traffic density and speed). A higher position refreshment rate leads to improved map quality at the expense of possible radio traffic overload, which can lead to packet losses and eventually a reduction in map quality.

IMPACT

In the healthcare use case, SG-HEART will be of great assistance in locating people awaiting rescue using low cost radio devices. In the transport use case, cooperation between cars and/or between cars and infrastructure is an issue currently considered in ETSI. Assessment of cooperation benefits in terms of local dynamic maps could accelerate their standardization in ETSI.

Publications

F.Wolff, K. Le Deroff, S. de Rivaz, N. Deparis, F. Dehmas, J.P. Cances «Benchmarking of Narrowband LPWA Physical Layer Ranging Technologies», 16th Workshop on Positioning, Navigation and Communications (WPNC), 23-24 Oct 2019, Bremen, Germany

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Valérian Mannoni
valerian.mannoni@cea.fr

Bernard Stree
bernard.stree@cea.fr



5G MiEdge

5G MiEdge: Millimeter-wave Edge cloud as an enabler for 5G ecosystem

The 5G MiEdge project is designing very high speed wireless services based on integrating two novel technologies: millimeter wave communications, which provide the access to multiple previously unused resources, and mobile computing, which allows very fast signal processing next to end users.

http://5g-miedge.eu/

Keywords
5G
Edge cloud computing
Millimeter-wave technology

5G MiEdge at a glance

36 months
Jul. 2016 > Jun. 2019

EC Programme
H2020-EUJ-01-2016

Project Coordinator
Fraunhofer Heinrich-Hertz-Institut (DE)

Partners
DE: Fraunhofer Heinrich-Hertz-Institut, Intel
FR: CEA-Leti
IT: Sapienza University of Rome, Telecom Italia
JP: KDDI R&D Laboratories Inc., Panasonic AVC Networks Company, Tokyo Institute of Technology

Total budget
€ 1,5 m.

EC Contribution
€ 1,5 m.

Contract Number
723171

Objectives

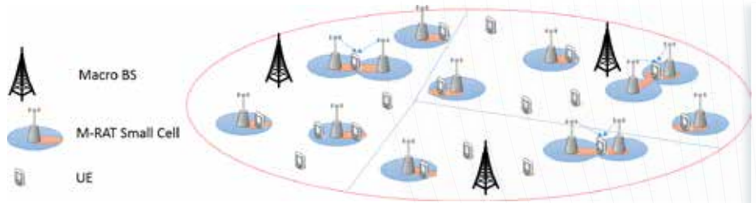
Project Aim 1. To research, develop and prove the 5G based MiEdge concept, whose viability is evaluated by detailed theoretical and numerical analysis and prototyped for proof of concept.
Project Aim 2. To develop transmission schemes and protocols of mmWave access/backhauling designed to assist the mobile edge cloud in caching/prefetching and thereby ensuring ultra-high speed, low latency service delivery resilient to network bottlenecks, such as backhaul congestion, user density and mission-critical service deployment based on three target scenarios: a stadium, an office and a train/station.
Project Aim 3. To develop novel ultra-lean and inter-operable control signaling over 3GPP LTE to provide liquid ubiquitous coverage in 5G networks based on acquisition of context information and forecasting of traffic requirements, thereby enabling proactive orchestration of mmWave edge cloud communication/computation resources.
Project Aim 4. To develop user/application-centric orchestration algorithms and protocols to adapt mmWave edge cloud radio and computation resources to 5G networks using traffic forecasting provided by liquid RAN C-plane. This will enable self-organized and proactive resource reservation and satisfy low-latency service requirements.
Project Aim 5. To develop a joint 5G test bed integrating mmWave edge cloud, liquid RAN C-plane and user/application-centric orchestration to foster 5G MiEdge's effective impact in Europe and Japan, and especially in preparing the 2020 Tokyo Olympic Games. The 5G MiEdge test bed is actively liaising with the other EU/JP consortium focusing on the network side to leverage synergies between alternative 5G concepts.
Project Aim 6. To contribute to defining 5G mobile communications standards in 3GPP and IEEE as well as in open forums, such as NGMN, Small Cell Forum and the International Telecommunication Union (ITU) Industry Specification Group MEC, in relation to mmWave access, liquid RAN C-plane and protocols for user/application-centric orchestration through coordination between its European and Japanese partners.

CEA-Leti in 5G MiEdge

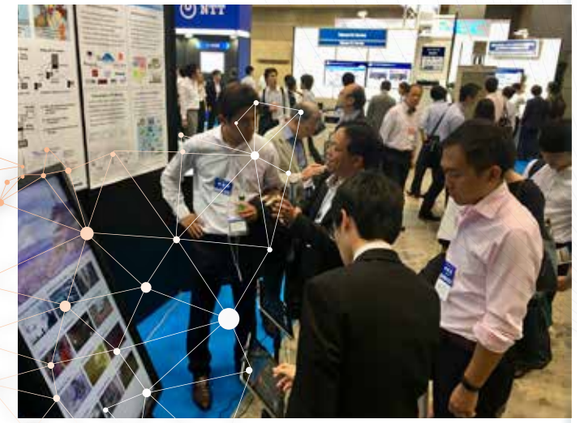
In the 5G MiEdge project, CEA-Leti has developed new solutions involving millimeter wave communications and mobile edge cloud technologies. The Institute has expanded its system level simulator to characterize and assess future mobile networks.

CEA-Leti's specific outcomes of 5G MiEdge are:

- Contributing to defining the 5G ecosystem, its management and operation
- Contributing to defining possible use cases, scenarios and system architecture in 5G MiEdge
- Investigating joint beam steering and beam forming mechanisms to improve user data rate and minimize co-channel interference in a mmWave access network
- Investigating stochastic geometry-based solutions to mathematically modelling network performance with respect to deployment parameters such as base station density, transmission power and antenna gains
- Designing learning mechanisms to draw up real-time context aware maps describing available communication and computation resources
- Designing clustering techniques aimed at finding a suitable clustering of communication and computation nodes
- Assessing proposed mechanisms through system level simulations
- Co-organizing dissemination at international conferences and scientific events. CEA-Leti is also supporting active links with other current projects involving CEA such as 5G Champion and Speed 5G
- Disseminating 5G MiEdge results through conferences and journal papers.



Example of network deployment with multiple radio access technologies. Small cells use both millimeter and sub6 GHz bands to provide jointly very high data rate and reliable coverage to the end users.
© CEA-Leti



This picture has been taken at 5G MiEdge booth in the 2017 Global 5G event and shows the Panasonic signage, which is based on millimeter wave technology to provide super high speed capacity in location such as train stations, airports, etc.
© CEA-Leti

IMPACT

The 5G MiEdge project is an important vector in 5G and beyond because it highlights the importance of millimeter-wave communication technologies in the new generation of mobile networks. Moreover, the project fosters close interaction between European and Asian ecosystems in relation to 5G and Beyond.

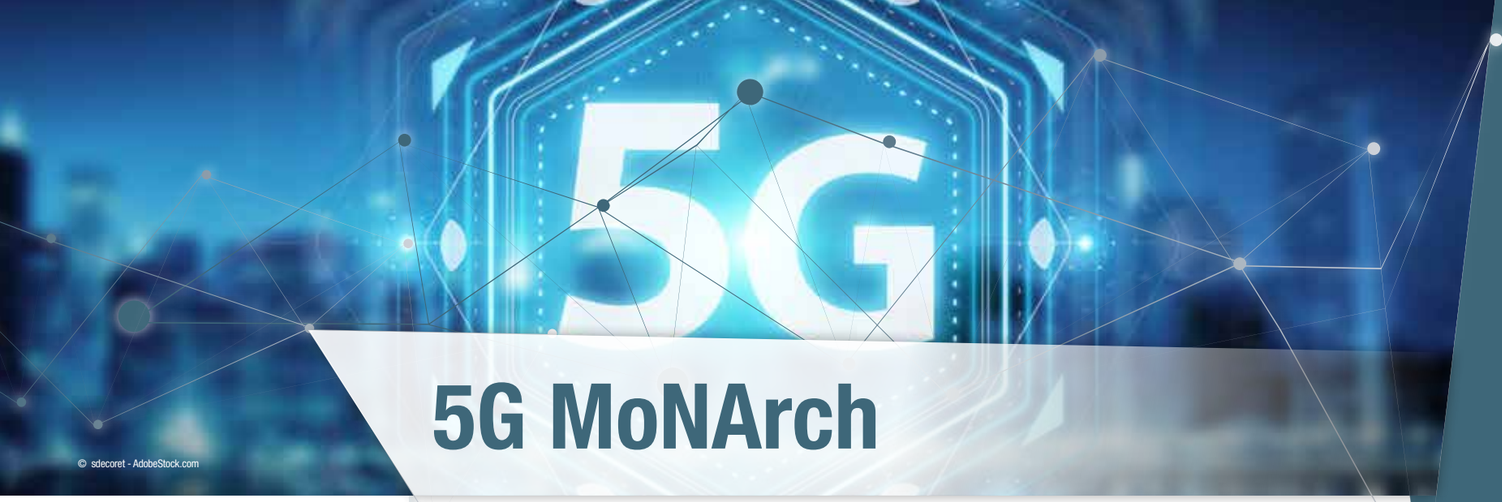
Publications

- *«Making 5G Millimeter Wave Communications a Reality», A. De Domenico, R. Gerzaguet, N. Cassiau, A. Clemente, R. D'Errico, C. Dehos, J. L. González, D. Kténas, L. Manat, V. Savin, and A. Siligaris, IEEE Communication Magazine, 2017 [invited paper].*
- *«Coverage Analysis and Load Balancing in HetNets with mmWave Multi-RAT Small Cells», G. Ghatak, A. De Domenico, M. Coupechoux, in IEEE Transactions on Wireless Communications, vol. 17, no. 5, pp. 3154-3169, May 2018. doi: 10.1109/TWC.2018.2807426.*
- *«Accurate Characterization of Dynamic Cell Load in Noise-Limited Random Cellular Networks», G. Ghatak, A. De Domenico, M. Coupechoux, (IEEE 88th Vehicular Technology Conference: VTC2018-Fall).*
- *«Modeling and Analysis of HetNets with mm-Wave Multi-RAT Small Cells Deployed Along Roads», G. Ghatak, A. De Domenico, M. Coupechoux, IEEE Global Communications Conference (GLOBECOM) 2017, Singapore.*
- *"Proactive Computation Caching Policies For 5G-and-Beyond Mobile Edge Cloud Networks», N. di Pietro and E. Calvanese Strinati, 2018 26th European Signal Processing Conference (EUSIPCO), Rome, 2018, pp. 792-796.*
- *«Resilient Design of 5G Mobile-Edge Computing Over Intermittent mmWave Links», N. di Pietro, M. Merluzzi, E. Calvanese Strinati, and S. Barbarossa, submitted to IEEE Transactions on Mobile Computing, Dec. 2018.*

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1 2 3 4 5 6 7 8 9

Antonio De Domenico
antonio.de-domenico@cea.fr

Bernard Strée
bernard.stree@cea.fr



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5G MoNArch

Objectives

5G Monarch is built around on five objectives.

1. Detailed specification and extension of the 5G architecture

2. Extension of architectural design with three key enabling innovations enabling operation of sliced 5G networks and specific functional extensions

3. Development of novel functional innovations demanded by two key technologies necessary to identified use cases

4. Deployment and experimental implementation of the architecture in two use cases

5. Evaluation, validation and verification of architecture performance.

https://5g-monarch.eu/

Keywords
5G
Network resiliency
Network slicing
Resource elasticity
Verticals

5G MoNArch at a glance

24 months
Jul. 2017 > Jun. 2019

EC Programme
H2020-ICT-07-2017 Future Internet

Project Coordinator
Nokia Solutions and Networks Management International GmbH (DE)

Partners
DE: Deutsche Telekom AG, Hamburg Port Authority, Huawei Technologies Duesseldorf GmbH, Nokia Solutions and Networks Management International GmbH, Nomor Research, University of Kaiserslautern
ES: ATOS SE, Universidad Carlos III de Madrid
FR: CEA-Leti, Nokia Bell Labs France
GR: Centre for Research & Technology Hellas, Mobics Ltd
IT: Telecom Italia
UK: Real Wireless, Samsung Electronics (UK) Limited

Total budget
€ 7.7 m.

EC Contribution
€ 7.7 m.

Contract Number
761445

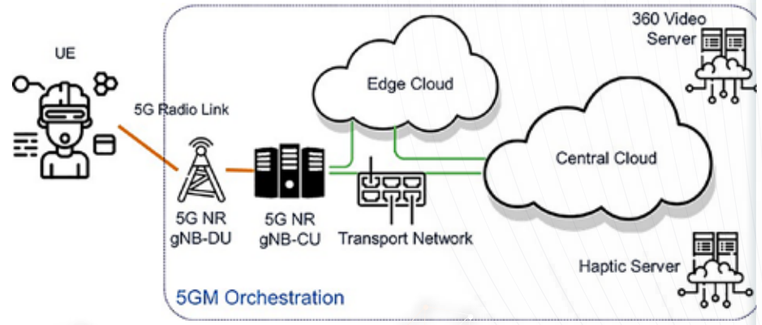
5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond

The 5G MonArch project team is investigating the technologies for enhancing the flexibility and robustness of future mobile networks in relation to meeting the heterogeneous requirements of the services foreseen in the 5G use cases.

CEA-Leti in 5G MoNArch

In 5G MonArch project, CEA-Leti has developed new solutions involving network virtualization, network slicing and 5G multiple radio access technologies. Most of these studies have focused on integrating artificial intelligence (AI) principles into 5G mobile networks. CEA-Leti has contributed to disseminating the work in the ETSI ENI ISG.
More specifically, CEA-Leti's specific contributions to 5G MonArch are:

- Contribution to 5G MonArch management
- Contribution to design of 5G MonArch architecture
- Investigation of cross slice resource orchestration mechanisms, which consider slice farness and priorities and increase 5G system elasticity through reinforcement learning
- Investigation of stochastic geometry-based solutions to model mathematically slice-aware load balancing across multiple coexisting radio access technologies
- Development of orchestration and RAN function extensibility in the 5G MonArch architecture with particular focus on elasticity aspects
- Design of mechanisms adapting network function placement in a hybrid cloud infrastructure to available computational resources and network load
- Design of unsupervised learning techniques that enable clustering of new service demands and existing network services such that the resources required by the new services are minimized
- Co-organization of dissemination events at international conferences and scientific events
- Dissemination of 5G MonArch results through conference and journal papers.



Example of network orchestration trough 5G MoNArch virtualization functionalities to enable wireless augmented reality services in future mobile networks.
© 5G MonArch IR5.2

IMPACT

Integration of 5G MonArch technologies in the 5G ecosystem will increase revenues by introducing new mobile services. Many of these new services will be tailored to the individual customer requirements so they are likely to be higher value (income/GB) business-to-business (B2B) services for verticals.

Furthermore, 5G MonArch technologies prompt lower cost per GB by providing a wide range of services from a single multi-service network.

Publications

- *«Optimal Cross Slice Orchestration for 5G Mobile Services,» D. T. Hoang, D. Niyato, P. Wang, A. De Domenico, E. Calvanese Strinati, IEEE VTC fall 2018.*
- *«Small Cell Deployment Along Roads: Coverage Analysis and Slice-Aware RAT Selection», (Revised version submitted to IEEE Transactions on Communications), G. Ghatak, A. De Domenico, M. Coupechoux.*
- *«Artificial Intelligence for Elastic Management and Orchestration of 5G Networks,» D.-M. Gutierrez-Estevez, M. Gramaglia, A. de Domenico, G. Dandachi, S. Khatibi, D. Tsolkas, I. Balan, A. Garcia-Saavedra, U. Elzur, Y. Wang, submitted to IEEE Wireless Communication.*
- *«Optimal Computational Resource Allocation and Network Slicing Deployment in 5G Hybrid C-RAN», A. De Domenico, Y.-F. Liu, and W. Yu, submitted to IEEE ICC 2019.*
- *«An Artificial Intelligence Framework for Slice Deployment and Orchestration in 5G networks», G. Dandachi, A. De Domenico, D. Thai Hoang, and D. Niyato, submitted to IEEE JSAC.*
- *«Optimal Virtual Network Function Deployment for 5G Network Slicing in a Hybrid Cloud Infrastructure», A. De Domenico, Y.-F. Liu, and W. Yu, submitted to IEEE JSAC.*

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Antonio De Domenico
antonio.de-domenico@cea.fr

Bernard Strée
bernard.stree@cea.fr



Clear5G

clear5G.eu

Keywords
5G networks
Converged access
Factories of the Future (FoF)
Internet of Things (IoT)
Machine type traffic
Mission critical
Mission Critical Communication (MCC)
Security
Verticals

Clear5G at a glance

30 months
Sept. 2017 > Feb. 2020

EC Programme
H2020

Project Coordinator
University of Surrey (UK)

Partners
FR: CEA-Leti
GR: Wings ICT Solutions Ltd
NL: Netherlands Organisation for Applied Scientific Research
TR: Argela, Turk Telekom
TW: Adlink Technology Inc., Fair Friends EnterpriseCo, Institute for Information Industry, National Taiwan University
UK: Toshiba Research Europe

Total budget
€ 3.5 m.

EC Contribution
€ 2.5 m.

Contract Number
761745

Converged Wireless Access for reliable 5G MTC for factories of the future

A Factory of the Future (FoF) is connected. Sensors provide information to be exchanged between machines or transmitted to a decision center. These sensors are wired at present. The aim of the CLEAR5G project is to investigate how 5G can help transform wired into wireless communication in this context.

CEA-Leti in Clear5G

Physical Layer Security

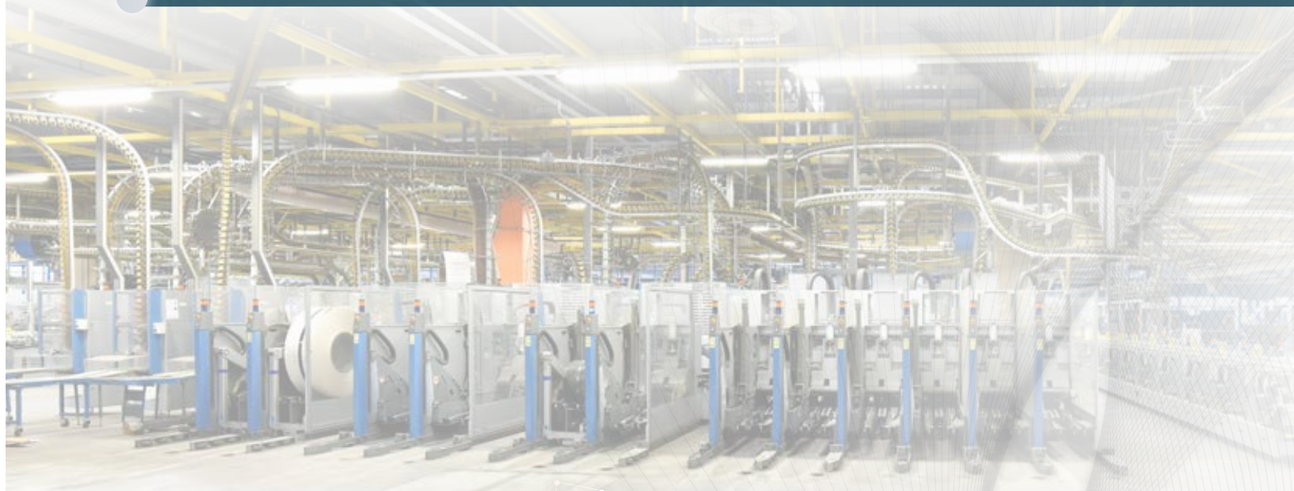
CEA-Leti has performed a state-of-the-art review of the sensitivity of 3G, 4G and the first standardized version of 5G NR (Release 15) to jamming attacks. CEA-Leti has reviewed the work of Technical Specification Group TSG-SA3, in charge of security issues, with a focus on the security of messages exchanged over the air interface (SUPI encryption, data confidentiality and integrity) and vulnerability to attacks by a quantum computer. CEA-Leti has focused on using AES-256 as a cryptographic algorithm for the FoF. The approach's main characteristic is that it is assumed that the adversary knows neither the plaintext nor the ciphertext, which is a usual assumption in conventional side channel attacks. A simulation environment was developed to validate the efficiency of the attack based on a message-passing algorithm. Its performance was established and it was shown to be theoretically efficient. The attack was implemented on a hardware item. However, careful characterization of information leakage showed that leakage in some operations could be exploited but was too weak in other operations required to run the message-passing algorithm. It was therefore impossible to certify the feasibility of the attack. A combination with other techniques (template attack or deep learning attack) should be investigated in response to this issue.

Heterogeneous Radio Access

Use of multiple heterogeneous radio access technologies and spectrum bands brings new challenges to MAC design. For example, how to select and switch between multiple radio access technologies is key to both resource utilization and individual performance in terms of throughput and latency. CEA-Leti has studied the performance and limitations of two Low Power Wide Area (LPWA) solutions, namely Turbo-FSK and LoRa, in terms of reliability, scalability, spectral efficiency, energy consumption and flexibility. The second step was to propose a dual technology network, in which LPWA technologies are used implemented with a 5G beacon for time synchronization. CEA-Leti has investigated how a scheduled version of LoRaWAN with an optimized allocation of its spreading factors (SFs) can outperform random SF allocation and increase the number of devices that can be simultaneously served.

Objectives

Clear5G's aim is to design, develop, validate and demonstrate an integrated convergent wireless network for Machine Type and Mission Critical Communication (MTC/MCC) services for Factories of the Future (FoF). Clear5G will deliver technical solutions addressing the challenges of mass deployment of connected devices, security, ultralow latency and ultra-high reliability in FoF applications including remote maintenance and closed loop control systems. The requirements of these complex scenarios will be met through convergence of different wireless technologies enabled by the protocol and architecture enhancements proposed by Clear5G.
Clear5G focuses on providing PHY, MAC and architectural enhancements to meet the strict requirements of FoF applications in terms of KPIs: latency, reliability, connection density, spectrum and energy efficiency and the project therefore contributes to ITU-R objectives (e.g. 1000-fold connection density) for the next generation mobile network.
The Clear5G team comprises a combination of successful, innovative, well-known, major European and Taiwanese corporations and SMEs along with research and academic institutions. The partners have proven know-how in architecture, resource management, protocol enhancements, standardization, prototyping and demonstration. Proof of concepts will be tested on Europe's 5GIC testbed, while final system demonstration of close integration and cooperation of the manufacturing sector and the Clear5G enhanced network will be implemented on Taiwan's III testbed.
Clear5G brings together a strong and diverse set of European and Taiwanese partners including partners from the FoF sector. The complementarity of team, skills and expertise brings added value to 5G research on both sides and will deepen international cooperation, serving as a showcase of 5G empowering vertical industries. The partners will contribute to relevant standardization in both the communication and the manufacturing domains.



IMPACT

CEA-Leti has evaluated a novel side channel attack on AES-256 that could be used in the context of the Factory of the Future. It effectiveness has been established based on simulation. Practical implementation of the attack could not be certified because the leakage extraction procedure was inefficient. Other leakage extraction techniques should be investigated to evaluate the vulnerability of hardware devices connected through 5G NR links. This work has not yet been published but could have an impact on the security of factories using 5G NR connections between devices.

CEA-Leti has developed new MAC layer functionalities, ensuring compatibility with the LoRaWAN standard MAC commands. Assuming an external beacon, CEA-Leti has developed an optimized SF allocation algorithm for LoRa uplink data packets. This new scheme allows an increase in the number of devices that can be simultaneously served compared with the conventional random SF allocation.

Publications

• *«Large Scale LoRa Networks: From Homogeneous to Heterogeneous Deployments», M. Nunez, L. Suraty, M. Maman, A. Duda IEEE WiMob 2018, the 14th International Conference on Wireless and Mobile Computing, Networking and Communications, Limassol, Cyprus 15-17 Oct 2018.*
• *«LPWA Deployment for Factory of the Future: LoRa or Turbo-FSK Based Technology?» A. Guizar, M. Nunez, V. Mannoni and M. Maman PIMRC 2019 IEEE 30th Annual International Symposium on Personal 8-11 Sept 2019.*

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1 2 **3** **4** 5 6 7 8 9

Sylvie Mayrargue
sylvie.mayrargue@cea.fr

Bernard Strée
bernard.stree@cea.fr



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EnABLES

Objectives

EnABLES integrates key European research infrastructures in powering the Internet of Things (IoT). Six research institutes and five knowledge hubs of excellence are focusing on long-term energy management for the self-powered smart sensor systems required by IoT innovation. The key challenge in developing truly 'invisible', unobtrusive, self-powered (autonomous) wireless devices is to bridge the gap between capturing energy supply from energy harvesting sources (EH), integrating new devices for energy storage (ES) and taking into account the micro-power management (MPM) requirements for miniaturized system operation. In providing access to unique infrastructure, world-leading expertise, advanced equipment and state-of-the-art technologies, EnABLES is mobilizing several hundred academic researchers and technologists to develop energy harvesting, storage and micropower management solutions for integrated design and deployment of miniaturized autonomous sensors. Access ranges from materials and models to devices and systems and its providers are working with the user community to accelerate adoption and innovation in real-life applications. EnABLES project integration offers a paradigm shift in building an infrastructure network that links new scientific knowledge with application-driven research. Specifically for energy management solutions, this represents a change in mindset to ensure earliest, synchronous, collaborative development of system-optimized IoT devices. This is a unique opportunity for Europe to maintain its global leadership in microsystem energy management and and its position at the heart of IoT innovation at a pivotal moment.

EnABLES

http://www.enables-project.eu/

Keywords
Energy Harvesting
Energy Storage
Internet of Things (IoT)
Micro-Power Management

EnABLES at a glance

48 months
Jan. 2017 > Dec. 2020

EC Programme
H2020-INFRAIA-2017

Project Coordinator
Tyndall (IR)

Partners
DE: Fraunhofer, Karlsruhe Institute of Technology
FR: CEA-Leti, CEA-Liten
GB: University of Southampton
IT: Politecnico di Torino, University of Bologna, University of Perugia
NL: PaulsConsultancy, Tass International
IR: Tyndall

Total budget
€ 5.2 m.

EC Contribution
€ 5.2 m.

Contract Number
730957

European Infrastructure Powering the Internet of Things

The ENABLES project brings together the main European research institutes in the field of microsources of energy applied to the Internet of Things. It enables academic researchers or SMEs to access a unique level of skill. The objectives are to disseminate the solutions and build a European ecosystem.

CEA-Leti in EnABLES

CEA-Leti has taken part in establishing a "powering the IoT" community with a change in mindset on how parts and systems are developed. CEA-Leti is now part of a strong network stimulating new collaborations.

As a member of the selection committee for transnational access enquiries, CEA-Leti has extended its knowledge of needs and solutions in the area of energy microsources.

CEA-Leti is involved in two approved enquiries from Russia and the United Kingdom. Specific key building blocks (thin film lithium layers, microbattery stacking process) developed at CEA-Leti are tested within the scope of these actions.

In parallel with Trans National Access actions, CEA-Leti is working on new building blocks to enhance its offer and portfolio in the area of powering the IoT. A specific positive electrode characterization methodology has been developed for use in solid-state lithium microbatteries. Raman spectroscopy was used on a layer cross section to map the different crystalline phases of the material within the electrode layer. This process has also provided a map at different battery charge states. This has enabled correlation of electrical performances with specific characteristics of the material and correlations with manufacturing parameters.



Microbattery manufacturing platform.
© CEA

IMPACT

Networking and clustering labs involved in Energy Storage, Energy Harvesting and Power Management. Transnational Access Actions have prompted two new collaborations between CEA-Leti and European SMEs involved in development of energy storage solutions. This organization is an efficient tool for reducing study costs on a first proof of concept and promotes the value of CEA-Leti know-how.

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Raphaël Salot
raphael.salot@cea.fr

Yves Quéré
yves.quere@cea.fr



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EnSO

EnSO
Energy for Smart Objects

http://www.enso-ecsel.eu/

Keywords
Internet of Things (IoT)
Micro energy sources
Smart microsystems

EnSO at a glance

48 months
Jan. 2016 > Dec. 2019

EC Programme
ECSEL 18-2015

Project Coordinator
CEA-Leti (FR)

Partners
BE: Prayon, UIG
CH: BASF
CZ: IMA
DE: AED Engineering, Fraunhofer, Mahle
DK: GNHearing
ES: CSIC-CNM, GNF, IDNEO, Ojmar
FR: Alpwise, Blumorpho, Cairdac, CEA-Leti, Editag, Enerbee, Gemalto, Solems, UFR, ULorraine, Valotec
NL: Evalan, Henkel, Maa-I, Maa-U, MeyerBurger, Nordson Dima, SKF, TNO

Total budget
€ 65.9 m.

EC Contribution
€ 16.8 m.

Contract Number
692482

Energy for Smart Objects

The scope of the EnSO project has encompassed energy solutions for powering "smart" objects in Smart Society, Smart Health and Smart Energy key applications. EnSO has developed micro-batteries with energy harvesting and power management for powering autonomous Smart Objects.

CEA-Leti in EnSO

The EnSo project has prompted major CEA-Leti contributions in the field of micro energy sources. Specific energy storage solutions based on thin film solid state lithium architecture have been developed.

The first component family featured vacuum deposition and advanced patterning methods such as photolithography band laser ablation, which allowed very tiny components (10s of mm²) to be manufactured with high energy densities (150 Wh/l was achieved and 300 Wh/l is imminent). Within the scope of the EnSO project, these components are embedded in advanced medical devices (dental, Pacemaker and hearing aids).

The second component family featured more standard lithium battery manufacturing techniques such as the slot die. In this case, breakthrough came from a new solid-state polymer electrolyte and specific ultra-thin packaging. The manufacturing process is well suited for applications, in which cost is a major concern while surface requirements are not overly demanding (> cm²).

Developments made during the project enabled us to achieve TRL8 level on a first generation of PVD microbatteries by transferring the manufacturing processes to a dedicated pilot line. In parallel, TRL 4-5 has already been obtained for the following generations and a TRL6 level is expected by the end of the project.

The batteries developed were integrated into Autonomous Micro Energy Sources with Energy Harvesters and Power Management before being delivered to end-user partners (15 application cases) for prototype manufacturing and testing.



CEA-Leti's Microbattery R&D manufacturing pilot line.
© CEA-Leti



Lithium Microbattery (First generation, TRL8).
© CEA-Leti



EnSO Autonomous Micro Energy Source Demonstrator.
© ENSO

Objectives

The goal of EnSO was to develop and consolidate a unique European ecosystem in the field of Autonomous Micro-Energy Sources (AMES) to support the European electronics industry in developing innovative products especially for IoT markets.
EnSO multi-Key Enabling Technologies (KET) objectives:
- To demonstrate the competitiveness of EnSO energy solutions for targeted key Smart Society, Smart Health and Smart Energy applications
- To disseminate EnSO energy solutions to foster their take-up by emerging markets
- To develop highly reliable assembly technologies involving shapeable micro-batteries as well as energy harvesting and power management building blocks
- To develop and demonstrate a high-density, low-profile, shapeable, long-lifespan, rechargeable micro-battery product family
- To develop customizable smart recharge and energy harvesting enabling technologies for AMESs
- To demonstrate EnSO pilot line capability and to investigate and assess upscaling of Autonomous Micro Energy Sources (AMES) competitive production for very high product volumes.

EnSO contributed market innovative energy solutions to prompt design differentiation in electronic smart systems. Generic building block technologies are customizable and EnSO manufacturing challenges have prompted high-throughput processes.

The ENSo ecosystem has involvesd the entire value chain from key materials and tools to multiple demonstrators in different application areas.

The EnSO project scope has addressed market replication and demonstration as well as technological introduction activities of the ECSEL Innovation Action work program.

EnSO corresponded to several of the ECSEL MASP strategic thrusts. its innovations in advanced materials, advanced equipment and multi-physics co-design of heterogeneous smart systems have contributed to the Semiconductor Process, Equipment and Materials thrust. AMES is a key enabling technology of Smart Energy key applications.

IMPACT

The prime aim of the EnSO project was to develop and consolidate a unique European ecosystem in the field of autonomous micro energy sources (AMES). This ecosystem spans the entire value chain from key materials and tools needed for anticipated cost and sufficient volumes to several demonstrators in different application fields.
EnSO enabled us to demonstrate the competitiveness and manufacturing readiness of EnSO energy solutions in Europe. It was also an efficient tool for disseminate and standardizing EnSO energy solutions with easy-to-use demonstration kits for a large number of application cases in areas of wide impact such as Smart Society and Smart Health.

Publications

- *«Insight into the formation of lithium alloys in all-solid-state thin-film lithium batteries», D. Goonetilleke, N. Sharma, J. Kimpton, B. Pecquenard, F. Le Cras, Frontiers in Energy Research, July 2018, Volume 6, Article 64.*
- *«Comprehensive characterization of all-solid-state Li/LiPON/LiCoO2 thin films commercial microbatteries by Electrochemical Impedance Spectroscopy», S. Larfaillou, D. Guy-Bouyssou, F. Le Cras, and S. Franger, Journal of Power Sources 319 (2016) 139-146D.*
- *«Dual cation- and anion-based redox process in lithium titanium oxysulfide thin film cathodes for all-solid-state lithium-ion batteries», V. Dubois, B. Pecquenard, S. Soulé, H. Martinez, F. Le Cras, ACS Appl. Mater. Interfaces.*
- *«Direct bonding and debonding approach of ultrathin glass substrates for high temperature devices», M. Bedjaoui, ECTC Florida June 2017.*
- *«Thin Film Processing for Innovative Solid State Lithium Batteries», S. Oukassi, ECS, Seattle, May 13-17.*

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Raphaël Salot
raphael.salot@cea.fr

Philippe Pantigny
philippe.pantigny@cea.fr



FED4SAE

FED4SAE

https://fed4sae.eu/

Keywords
Competency
Cyber Physical Systems (CPS)
Digital Innovation Hub (DIH)Embedded systems
Go-to-market
Innovation support
Platforms
SME
Startups

FED4SAE at a glance

36 months
Sep. 2017 > Aug. 2020

EC Programme
Smart Anything Everywhere Inititiative / ICT-04-2017

Project Coordinator
CEA-Leti (FR)

Partners
AT: AVL
CH: CSEM
DE: Fortiss, Fraunhofer
ES: Unican
FR: BLUMORPHO, CEA-Leti, STMicroelectronics, Thales
GB: Digital Catapult
HU: DME
IE: Intel
IT: STMicroelectronics
SE: KTH

Total budget
€ 7.6 m.

EC Contribution
€ 6.9 m.

Contract Number
761708

Federated CPS Digital Innovation Hubs for the Smart Anything Everywhere Inititiative

The FED4SAE project is helping to accelerate marketing of European cyber-physical systems and embedded solutions by, 1/ providing access to leading edge CPS platforms, advanced technologies and testbeds owned by industrials and R&D centers, 2/ providing technical coaching by experts in each field along with innovation management support, 3/ offering financial support and access to further VC funding and, 4/ access to potential users and suppliers across pan-European value chains.

Objectives

The overall ambition of the FED4SAE Innovation Action (IA) is to boost and sustain digitization of European industry by strengthening competitiveness in Cyber-Physical Systems (CPS) and embedded system markets. In line with the goals of the «Smart Anything Everywhere» initiative, FED4SAE is:

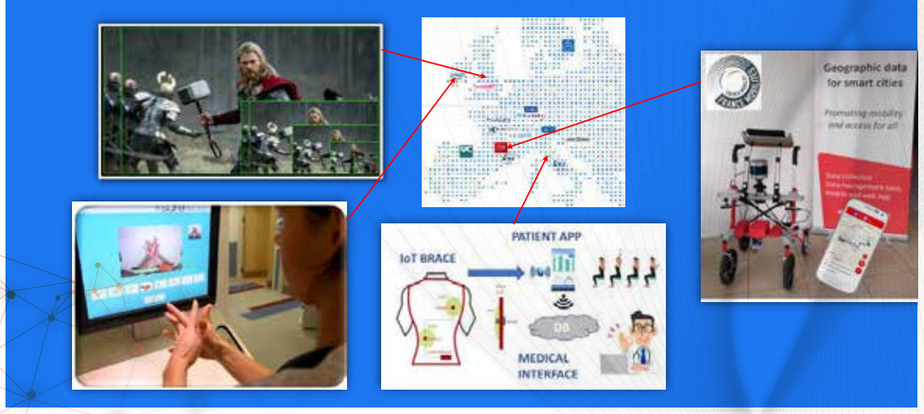
- Creating a pan-European network of Digital Innovation Hubs (DIHs) by leveraging existing regional ecosystems across entire value chains and a wide range of competencies. DIHs are enabling innovative technical and non-technical third parties (startups, SMEs and mid caps) from all sectors to build new «digital inside» products and services
- Acting as a European added-value, one-stop-shop to facilitate innovators/supplier, cross-border partnerships, which will accelerate European third party innovation in products and processes by providing technical, industrial and innovation management expertise. This is leading to quantifiable third party growth in market shares, productivity and industrial capacities, and broader adoption of CPS and embedded system solutions
- Linking DIH innovators to investors to reach out to further funding opportunities and enable forthcoming steps in third party developments after completing necessary application experiments (AEs)
- Ensuring self-sustainability of DIHs within a pan-European network by developing cooperation with regional organizations and key stakeholders providing public and or private investment for funding FED4SAE network activities.

The FED4SAE project work is based on key learning from the EuroCPS, the Gateone project and CPSE Labs IAs. FED4SAE is leveraging best practices in third party commitment, submission, evaluation and selection of AEs. The project is giving birth to a competitive ecosystem, in which European startups, SMEs and mid caps are thriving through access to leading technology sources, competencies and industrial platforms as well as to efficiently connected business infrastructures and existing regional innovation hubs.

CEA-Leti in FED4SAE

CEA-Leti is the project coordinator of the FED4SAE project, as it was for the EuroCPS project. Both projects are part of the European Smart Anything Everywhere (SAE) initiative to support European industry digitization by together proposing advanced technologies, competency and expertise partners, industrial platform providers and innovation management support. CEA-Leti and the FED4SAE partners have already successfully organized two open calls for finance and the selection process for application experiments. To date, 16 application experiments have received grants and sixteen more are expected to following the last, final open call. Experiments already selected are cross-border, while one involves eight SMEs in eleven different European countries, two of which are not directly represented by an FED4SAE partner. These initial results show the efficiency of the cascade funding cooperation model for initiating and boosting synergies between SMEs, major CPS-platforms and CPS-competency providers from different European countries. The CEA Open Innovation Centre (OIC) team is taking advantage of FED4SAE to roll out its activity in a European and cross-border context through its relations with SMEs outside the Grenoble ecosystem and the FED4SAE partners in addition to its project coordination work, CEA-Leti is fulfilling its objective of three selected application experiments. These industrial experiments are in different technical fields: «Sigma Fusion» (Automotive Sensor Fusion platform), smart home, health and transportation, and optimized data compression technics. At the same time, the CEA OIC team is establishing design-to-cost methodology, which as being tested on FED4SAE grant-based projects.

The FED4SAE project is allowing CEA-Leti to demonstrate its capacity to remove the risk of SME innovation and is reducing the development time for CPS and embedded systems.



FED4SAE success stories au CEA-Leti.
© CEA-Leti

IMPACT

The three FED4SAE open calls for finance have attracted 165 startups/SMES/mid caps from 34 countries and have resulted in submission of 116 high-quality proposals leading to selection of 32 projects from 13 countries (38% from countries not represented by FED4SAE partners), of which 97% are cross-border. The grant-awarded projects target a wide range of application domains: 28% smart sensors, 19% smart city and smart SW, 10% smart health and the remainder smart agriculture, mobility, home, transportation and teaching.

Isabelle Dor
isabelle.dor@cea.fr

Dider Belot
didier.belot@cea.fr



HIGHTS

www.hights.eu

Keywords
Autonomous driving
Connected cars
Hybrid data fusion
Intelligent transport systems
Localization and navigation
Road users safety
Vehicle-to-everything connectivity
Vehicle-to-vehicle cooperation
Vehicular ad hoc networks

Hights at a glance

36 months
May 2015 > Apr. 2018

EC Programme
H2020-MG-3.5a-2014 _2Stages: mobility for growth

Project Coordinator
Jacobs University Bremen (DE)

Partners
DE: German Aerospace Center, Ibeo Automotive Systems, IT21 Robert Bosch, Objective Software, Zigpos
FR: BeSpoon, CEA-Leti, Eurecom
LU: FBConsulting
NL: PaulsConsultancy, Tass International
SE: Chalmers University of Technology Gothenburg

Total budget
€ 6.0 m.

EC Contribution
€ 6.0 m.

Contract Number
636537

High Precision Positioning For Cooperative-Intelligent Transport Systems

In an autonomous driving context, vehicle connectivity can boost the accuracy (to 25 cm) of conventional satellite-based navigation systems through position information sharing with other vehicles or from roadside stations and on-board sensor data fusion (speed counters, inertial units, etc.).

CEA-Leti in Hights

• Design and proof-of-concept validation of cooperative algorithms for high-accuracy vehicle positioning (within ~ 0.25 m) relying on standardized technologies (e.g. ITS-G5 V2X connectivity, GNSS absolute positioning, Impulse Radio - Ultra Wideband relative ranging) and with a limited footprint in vehicle-to-vehicle (V2V) communications (in terms of channel congestion, overhead, latency), including:
- A flexible hybrid data fusion framework based on advanced Bayesian filtering
- Selection mechanisms based on theoretical performance bounds, integrating only the most informative contributions from neighboring vehicles (e.g. based on Bayesian performance bounds)
- Optimized V2V broadcast policies (i.e. controlling transmit power, message payload and transmit rate, parametric message approximation) to ensure virtually constant localization accuracy, while complying with standardized decentralized congestion control mechanisms and message size
- Mitigation of harmful effects inherent to V2V cooperation at both signal processing and scheduling levels (e.g. space-time correlations of fused observations, particle depletion and filter overconfidence in high-dimensional problems, error propagation among vehicles, poor dilution of precision in the cross-track dimension, etc.)
- Vehicle-to-infrastructure extensions of the cooperative fusion framework to mitigate long-term GNSS denials.

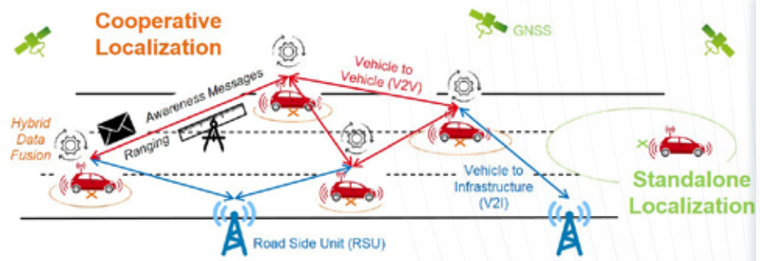
• Refinement of existing V2V radio channel models (e.g. geometry-based stochastic model implementation) and unprecedented vehicle-to-pedestrian channel sounding/characterization.

• Studies and recommendations regarding the integrity/security of cooperative V2x radio links against jamming and interception attacks.

• Contributions to integration and final proof-of-concept demonstration of the V2V-aided cooperative localization system at project consortium level (including 4 equipped vehicles on a highway section).

Objectives

Cooperative - Intelligent Transport System (C-ITS) applications require precise knowledge of vehicle geographical positions. Unfortunately, conventional satellite-based navigation systems (e.g. GPS and Galileo) cannot provide sufficient accuracy in practical operating environments (e.g. urban canyons, tunnels) or else they can suffer from excessive convergence times (cold start). The HIGHTS project has addressed this problem by combining V2X data communications (e.g. relying on the ITS-G5 standard), GNSS/GPS data, ranging technologies (e.g. based on Ultra Wideband) and, optionally, other on-board sensor measurements (e.g. LIDAR, camera lane detection, inertial navigation units, wheel speed counter, etc. when available). Specific semantic representations have also been proposed to manage and share multi-layer Local Dynamic Maps (LDM) among vehicles and/or infrastructure. LDMs account for the relative positions of passive and/or cooperative entities around each vehicle as well as those of geo-referenced active road side units, etc.…to support new cooperative localization functions and to extend the nominal perception range of each vehicle. Relevant contributions are intended for possible integration into the "facilities" layer of the "C-ITS station" communication architecture (ISO/ETSI), thereby ensuring availability to various applications in challenging use cases such as autonomous driving and platooning. As a contribution to defining a European-Wide Positioning Service Platform (EWPSP), the HIGHTS system architecture has also been advanced to select contextually the best combination of positioning algorithms depending on the context (i.e. environment, available sensor data) and the needs of the applications and services running on top (typically, an a priori accuracy class). Finally, the project context has prompted integration of a scaled proof-of-concept system demonstrator involving up to 4 cooperating vehicles. Experimental validations conducted on a highway section have shown that significant performance gains can be achieved through V2X cooperation (typically, within 0.25m accuracy in steady-state regimes) compared with standard standalone GNSS capabilities (typically, above 2m accuracy or even under GNSS denial).



Example of improved vehicle localization through vehicle-to-vehicle cooperation, performing locally the fusion of asynchronous awareness messages from neighbors, ranging measurements and on-board GNSS data (vs. standalone GNSS-based localization).
© CEA-Leti



Zoom on one of the four connected vehicles involved in field trials conducted on a portion of highway (equipped with both RTK and standard GPS, ITS-G5 V2X connectivity modules, ultra wideband ranging devices, inertial units, wheel speed counter and LiDAR…).
© HIGHTS consortium

IMPACT

In general terms, HIGHTS' concept and platform pave the way for upcoming road safety applications and higher automation levels, thus contributing to reducing fuel consumption and (near-)crashes. HIGHTS has contributed to ETSI standardization (TC ITS) regarding the format of V2X messages for high-accuracy localization or the format and interfaces of Local Dynamic Maps. The developed system architecture (complying with EWPSP and ETSI visions) is open so as to authorize integration of new technologies.

Publications

• "Implicit Cooperative Positioning in Vehicular Ad Hoc Networks", G. Soatti, M. Nicoli, N. Garcia, B. Denis, R. Raulefs, H. Wymeersch, IEEE Transactions on Intelligent Transportation Systems (IEEE Trans. ITS), Vol. 19, Is. 12, pp. 3964-3980, March 2018.
• "Breaking the Gridlock of Spatial Correlation in GPS-aided IEEE 802.11p-based Cooperative Positioning", G.-M. Hoang, B. Denis, J. Härri, D. Slock, IEEE Transactions on Vehicular Technology (IEEE Trans. VT), Connected Vehicles Series, Vol. 65, Is. 12, pp. 9554-9569, Aug. 2016.
• "Cooperative Localization in VANETs: An Experimental Proof-of-Concept Combining GPS, IR-UWB Ranging and V2V Communications", G.-M. Hoang, B. Denis, J. Härri, D. Slock, IEEE Workshop on Positioning, Navigation and Communications 2018 (IEEE WPNC'18), Bremen, Oct. 2018.
• "Wideband Pedestrian to Vehicle Propagation Channel Characterization and Modeling", G. Makhoul, R. D'Errico, C. Oestges, European Conference on Antennas and Propagation 2018 (EuCAP'18), London, April 2018.
• "Rethinking Cooperative Awareness for Future V2X Safety-critical Applications", I. Khan, G.-M. Hoang, J. Härri, IEEE Vehicular Networking Conference 2017 (IEEE VNC'17), Torino, Nov. 2017.
• "Robust and Low Complexity Bayesian Data Fusion for Hybrid Cooperative Vehicular Localization," G.-M. Hoang, B. Denis, J. Härri, D. Slock, IEEE International Conference on Communications 2017 (IEEE ICC'17), Paris, May 2017.
• "Cooperative Localization in GNSS-aided VANETs with Accurate IR-UWB Range Measurements", G.-M. Hoang, B. Denis, J. Härri, D. Slock, IEEE Workshop on Positioning, Navigation and Communications 2016 (IEEE WPNC'16), Bremen, Oct. 2016 > Best Paper Award.
• "On Communication Aspects of Particle-Based Cooperative Localization in GPS-aided VANETs", G.-M. Hoang, B. Denis, J. Härri, D. Slock, IEEE Intelligent Vehicles Symposium (IEEE IV'16), Workshop on Cooperative Communication and Positioning (CCP), Gothenburg, June 2016.

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Benoît Denis
benoit.denis@cea.fr

Bernard Strée
bernard.stree@cea.fr



INSIGHT

http:// www.insight-h2020.eu

Keywords
III-V
CMOS
GaAs
Integration
Nanowire
RF
Silicon Platform

INSIGHT at a glance

42 months
Nov. 2015 > May 2019

EC Programme
H2020-ICT-2015

Project Coordinator
Lund University (Sw)

Partners
CH: IBM
FR: CEA-Leti
GB: University of Glasgow
GE: Fraunhofer
IR: Tyndall

Total budget
€ 3.5 m.

EC Contribution
€ 3.5 m.

Contract Number
688784

Integration of III-V Nanowire Semiconductors for next Generation High Performance CMOS SOC Technologies

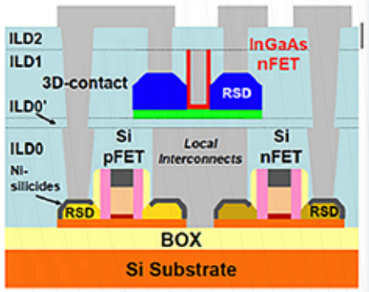
The overall objective of the INSIGHT project is to enhance advanced CMOS RF and logic capability by using III-V hetero-structure nanowires monolithically integrated on a silicon platform.

CEA-Leti in INSIGHT

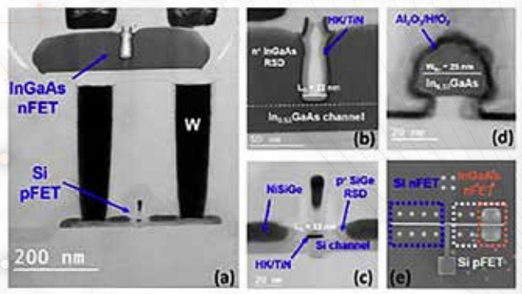
CEA-Leti is working on the technology stack comprising FDSOI CMOS (28nm) and InGaAs NFET developed by IBM. The III-V transistors are located in the back end of line of the FDSOI technology. Results have been presented for VLSI on a mixed FDSOI CMOS – III-V NFET DRAM circuit. CEA-Leti has delivered the Grand Signal model of the NFET and has supported the Fraunhofer Institute, which has delivered a Design Kit (DK). CEA-Leti then used this DK for benchmarking on mmW PA functions. Furthermore, CEA-Leti is in charge of WP benchmarking and operation. It delivers an updated operating plan each year and organizes an industry tour to acquire feedback from Micro & Nanotech Industrials such as ST, SOITEC, GF and INFINEON.

Objectives

The INSIGHT project team has identified a set of demonstrator circuits that match end-user need within or associated with the consortium. Circuit specifications have been drawn up, from which required technology development and related technical specifications at transistor level have been derived. Finally, necessary progress in materials and processes has been identified.
The project is focusing on:
• Developing and assessing performance of silicon-based, 94 GHz III-V nanowire MOSFET, low-noise amplifiers. The technology is creating a way of reducing the cost of key mm-wave components for high-bandwidth wireless applications
• Developing III-V nanowire MOSFETs on Si with breakdown voltages of 3-6 V and assessing their performance in mm-wave (90 GHz) power amplification circuits. These devices will increase the output power available from Si CMOS-compatible, mm-wave technologies to offer benefits in terms of transceiver range and sensitivity
• Building the basic blocks for future RF-circuits including mixers, voltage-controlled oscillators and frequency dividers for prescalers using silicon-based, III-V nanowire MOSFETS
• Developing science and technology underpinning all-III-V nanowire CMOSs on silicon for future technology nodes for 10 nm and below. This will be validated by implementing and dynamically characterizing a flip-flop to demonstrate co-integration of III-V, n- and p-type nanowire MOSFETs.



V. Deshpande, et al., VLSI Technology, accepted (2017)



3D Integration scheme demonstrated

© CEA-Leti

Publications

• "Facet-selective group-III incorporation in InGaAs Template Assisted Selective Epitaxy", M. Borg, & all, Nanotechnology 30, 8, 084004 (2019).
• "Electrical properties of Vertical InAs/InGaAs Heterostructure MOSFETs", O.-P. Kilpi, & all, J. Electron, Dev. Soc. In press 2018.
• "Electrical properties of metal/Al2O3/In0.53Ga0.47 As capacitors grown on InP", P. Ferrandis, & all, J. Appl. Phys. 123, 16, 161534 (2018).
• "Profiling Border-Traps by TCAD analysis of Multifrequency CV-curves in Al2O3/InGaAs stacks", E. Caruso & all, 2018 IEEE EUROSOI-ULIS (2018).
• "High Performance Quantum Well InGaAs-On-Si MOSFETs With sub-20 nm Gate Length For RF Applications", C.-B. Zota, & all, IEEE Internat. Electron Dev Meeting 2018, 39.4 (2018).
• "High Gain 220 - 275 GHz Amplifier MMICs based on metamorphic 20 nm InGaAs MOSFET Technology", A. Tessmann, & all, 2018 IEEE BiCMOS Comp. Semicond. Integr. Circ. Techn. Symp. (2018).

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Dider Belot
didier.belot@cea.fr



INSPEX

«http://www.inspex-ssi.eu/

Keywords
Environment perception
Integrated system
Lidar
Range sensors
Smart white cane
Ultrasound
UWB radar

INSPEX at a glance

36 months
Jan. 2017 > Dec. 2019

EC Programme
H2020-ICT-03-2016

Project Coordinator
CEA-Leti (FR)

Partners
BE: University of Namur
CH: CSEM SA
FR: GoSense
GB: University of Manchester
IE: Cork Institute of Technology, SensL, Tyndall – University College of Cork
IT: STMicroelectronics

Total budget
€ 4.5 m.

EC Contribution
€ 3.9 m.

Contract Number
730953

Integrated Smart Spatial Exploration System

The INSPEX project adapts obstacle detection commonly implemented in autonomous cars to portable applications, including guidance for visually impaired and blind people, robotics, drones and smart manufacturing. It detects obstacles in 3D under different environmental conditions (smoke, fog, heavy rain/snow, darkness, etc.).

CEA-Leti in INSPEX

CEA-Leti is project coordinator and leader of activities involving context awareness and user feedback, for which the Institute is in charge of system firmware, the obstacle detection function (performed with SigmaFusionTM) and obstacle speed estimation. It is contributing to activities involving submodule characterization, modelling and optimization as well as system design and development. The latter comprises design, optimization and manufacturing of a Ultra-Wide Band RF radar at 8GHz. CEA-Leti is also managing testing of prototypes prior to their validation by visually impaired and blind people.

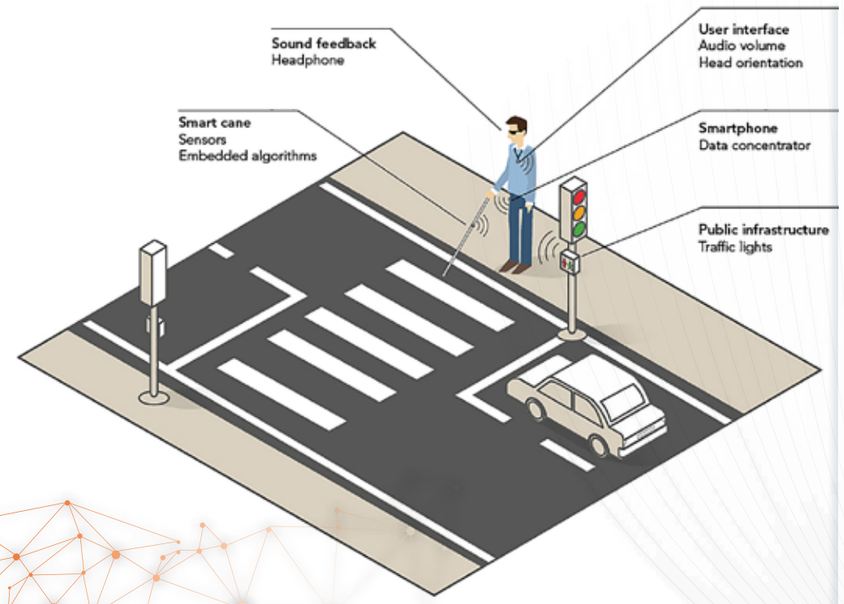
INSPEX is also addressing legal and ethical issues that development of a Class III medical device may encounter.

Objectives

INSPEX makes obstacle detection capabilities, currently only feasible in autonomous vehicles, available as a personal portable/wearable, miniaturized, multi-sensor, low-power spatial exploration system. The INSPEX system is used for real-time 3D detection, location and warning of obstacles under all environmental conditions in indoor and outdoor environments featuring static and mobile obstacles. Applications include navigation for visually/mobility impaired people, safer human navigation in reduced visibility conditions and small robot/drone obstacle avoidance.

The consortium partners are provided the project state-of-the-art range sensors (LiDAR, UWB radar and MEMS ultrasound) to the project. INSPEX miniaturizes these sensors and reduces their power consumption to meet the user requirements in terms of integrated system size and weight. They are integrated in a miniature, low power system together with an Inertial Measurement Unit, environmental sensing, signal and data processing, wireless communications, power efficient data fusion with SigmaFusionTM and a user interface for operation in wider smart/IoT environments.

The main INSPEX demonstrator embeds the INSPEX system in a white cane for the visually impaired; it provides 3D spatial audio feedback on obstacle location.



CEA SigmaFusion™ and UWB radar to serve the blind handicap.
© INSPEX

IMPACT

Range sensors (LiDAR, radar, ultrasound) have been miniaturized and each features a specific route to its usage, especially in the consumer sector. The project partners have also applied for patents. CEA has proposed an innovative grid-based localization technique offering low computational cost and estimation of speed and position via merging of information from Ultra-Wide Band radar and the Inertial Measurement Unit.

Publications

- *«Data protection and Biobanks in 2018», J. Herveg, Br. Nijhoff, European Journal of Health Law, pp. 515-536, 2018.*
- *«INSPEX: Integrated portable multi-sensor obstacle detection device. Application to navigation for visually impaired people», O. Debicki, N. Mareau, L. Ouvry, J. Foucault, S. Lesecq, G. Dudnik, M. Correvon, Design and Automation Conference DAC, IP-Track (best presentation award), San Francisco, USA, 2018.*
- *"INSPEX: design and integration of a portable/wearable smart spatial exploration system", Suzanne Lesecq, et al. Design, Automation and Test in Europe conference (DATE'17), Lausanne, Switzerland. 2017.*

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Suzanne Lesecq
Suzanne.lesecq@cea.fr



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SECREDAS

Objectives

SECREDAS aims to develop and validate multi-domain architecting methodologies, reference architectures and components for autonomous systems by combining high security and privacy protection, while preserving functional safety and operating performance.



https://www.ecsel.eu/projects/secredas

Keywords
5G
Automotive
Lidar, Radar
Safety
Security

SECREDAS at a glance

36 months
May 2018 > Apr. 2021

EC Programme
ECSEL

Project Coordinator
NXP Semiconductors Netherlands BV (NL)

Partners
AT: AIT, AVL, Cisc Semiconductors, Secinto, Thalès Austria, Virtual Vehicle
BE: IMEC, Transport & Mobility Leuven,
CZ: Budapest University of Technology, Institute of Microelectronic Applications
DE: AVL, Fraunhofer, Giesecke+Devrient Mobile Security, Merantix, NXP Semiconductors, Roche, Senetics Healthcare Group, Technical University of Kaiserslautern, ZF Friedrichshafen
ES: Advanced Automotive Antennas FICO, FICOSA ADAS, INDRA Systems, CSIC,TST,
FI: Haltian, Nokia, Solita, University of Oulu
FR: Canon Research Centre France, CEA-Leti, Gemalto, IDEMIA, IFSSTAR, In2car, Internet of Trust, ISSM Invia, PSA, Prove and Run, YoGoKo
GB: NXP
HU: Commsignia, University of Budapest
IT: Evidence, Ideas & Motions, Magneti Marelli, University of Modena & Reggio Emilia
NL: Catholic University of Nijmegen, Fastree3D, IMEC-NL, Municipality of Helmond, Philips, TNO, Ubiqu Access, Technical University of Eindhoven
PL: Technical University of Gdansk
PT: Beyond Vision, Infrastructures of Portugal, Institute of Telecommunications, IP Telecom, PDM&FC
RO: University Polytechnical of Bucarest
SE: RISE, China-Euro Vehicle Technology, Technology Nexus Secured Business Solutions
TN: ENIT, SUPCOM

Total budget
€ 51.5 m.

EC Contribution
€ 51.5 m.

Contract Number
783119

Product Security for Cross Domain Reliable Dependable Automated Systems

Development of autonomous, connected cars may be hampered by the fact that potential buyers do not trust them to be secure. The SECREDAS project is dedicated to taking a huge step involving the safety, security and privacy of these future vehicles.

CEA-Leti in SECREDAS

Radars and lidars are two of the main sensors enabling car autonomy in a globally safer ecosystem. Their raw data need to be processed to obtain Occupancy Grids (OGs), i.e. a map of obstacles (fixed or mobile) surrounding the vehicle. However, on-board calculations must not be over-complex in order to save battery energy. CEA-Leti has developed an approach for computing OGs from RADAR measurements. The resulting OG will serve as an input for a lightweight data fusion algorithm that will enable LIDAR and RADAR data to be combined to create a map of the vehicle surroundings.

Automotive radars are expected to operate in the millimeter wave (mmWave) frequency domain so CEA-Leti has also investigated various aspects of their integration within a communication-radar-localization multi-service framework, which relies on V2X wireless links to other connected vehicles and/or fixed road infrastructure elements. Based on characterization of theoretical performance bounds in multi-user and multi-carrier contexts, CEA-Leti initially studied how optimized beamforming could enhance estimation of intermediate location dependent radio variables (e.g. delay and angles of departure/arrival of transmitted mmWave signals) and thus moving vehicle position/orientation. Non-trivial operating trade-offs were then highlighted among these intricate services (typically between spatial resolution, rate coverage and latency). As a result, several resource allocation schemes have been proposed (over time/frequency/users) along with location-based beam optimization/alignment strategies. Finally, by exploiting multipath departure/arrival angles in sparse mmWave channels, CEA-Leti has considered applying simultaneous localization and mapping (SLAM) algorithms to calculate the positions of moving vehicles and passive scattering obstacles in the vicinity, thus paving the way towards opportunistic radar functions over V2X communication links.

IMPACT

The SECREDAS project contributes to ensuring faster deployment of autonomous/ connected cars by developing appropriate enabling technologies.

Radars and lidars are key to autonomous car development. However, on-board processing of their measurement data drains the car battery. It is therefore of utmost importance to reduce the energy consumption of the relevant data fusion algorithms. Future radars will operate in the millimeter spectrum (79GHz) so vehicle communication (between cars and/or car/infrastructure) at these frequencies can also be used to ensure accurate, opportunistic localization of surrounding vehicles and/or obstacles, thereby providing information additional to that from conventional radars and lidars.

Publications

- *«Localization and Throughput Trade-off in a Multi-user Multi-carrier mm-Wave System», R. Koirala, B. Denis, B. Uguen, D. Dardari, H. Wymeersch, IEEE Access, Vol. 7, Is. 1, Dec. 2019.*
- *«Localization and Communication Resource Budgeting for Multi-user mmWave MIMO», R. Koirala, B. Denis, B. Uguen, D. Dardari, H. Wymeersch, IEEE Workshop on Positioning, Navigation and Communications 2019 (IEEE WPNC'19), Bremen, Oct. 2019.*

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Sylvie Mayrargue
sylvie.mayrargue@cea.fr

Bernard Strée
bernard.stree@cea.fr



SPEED5G

speed-5G.eu

Keywords
5G
DSA
HetNets
Interference management
Multi-RAT MAC
Novel waveforms

SPEED5G at a glance

36 months
Jul. 2015 > Jun. 2018

EC Programme
H2020-ICT-14-2014
Advanced 5G Network Infrastructure for the Future Internet

Project Coordinator
University of Surrey (UK)

Partners
DE: Eurescom, Intel Germany GmbH, Rhode-Schwartz
GB: BT, University of Surrey
FR: CEA-Leti
GR: Intracom Telecom, Wings ICT Solutions
PT: Instituto de comunicações

Total budget
€ 5.6 m.

EC Contribution
€ 5.6 m.

Contract Number
671705

Quality of Service Provisioning and capacity Expansion through Extended-DSA for 5G

5G is expected to allow much higher throughputs than 4G. Using the WiFi band as a complement to 5G is planned to boost transmission speed on both 5G and WiFi bands. The SPEED-5G focuses on how these frequency bands can be shared and develops the necessary building blocks to optimize throughput in very dense network deployments.

CEA-Leti in SPEED5G

CEA-Leti's main contributions to the SPEED-5G project involve MAC design, resource management for 5G traffic and real-time implementation. On the MAC side, CEA-Leti has defined a medium access control protocol, which aims to exploit the time/frequency characteristics of 5G-NR-compliant waveforms. On the RRM side, CEA-Leti has contributed to providing a RRM algorithm designed for channel selection decision-making based on reinforcement learning. As far as implementation is concerned, CEA-Leti has provided a real-time PHY/MAC system, which has been integrated into the project testbed.

The outcomes of the project include:

• **Specification and validation of a MAC protocol** for broadband traffic supporting various Quality-of-Service (QoS) requirements, operating on the 5 GHz band and complying with the European regulation (listen-before-talk). This MAC protocol has been implemented in real time on a custom hardware platform and integrated into the project test bed.

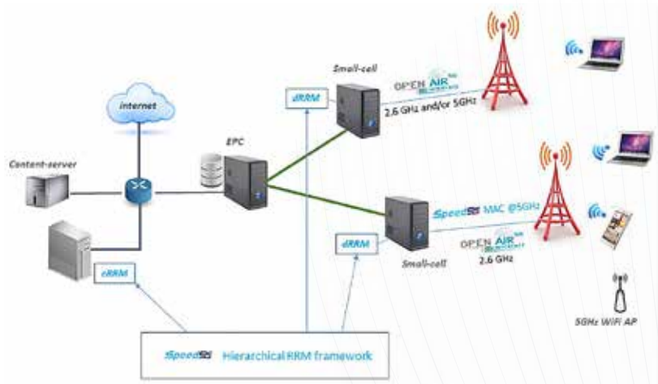
• **Specification and validation of an RRM algorithm for channel selection based on reinforcement learning**, which exploits the LBT nature of the MAC protocol. This algorithm is based on the Multi-Armed bandit framework and has showed promising results in simulations of synthetic scenarios. **This algorithm has been described in a patent application which has now been filed.**

• The MAC/RRM designs have been implemented on custom HW/S platforms and have been validated in real-life deployment though over-the-air demonstration of video streaming in the 5GHz band. **This implementation was notably demonstrated during the SPEED-5G public event** held on BT premises in London. The demonstration showed that great performance coexisted with corporate WIFI access-points.

• **CEA-Leti's work has been disseminated through two journal papers, four conference papers and a demonstration made during a conference.**

Objectives

With the advent of 5G, exponential traffic growth may lead to spectrum crunch. SPEED-5G proposes relying on a 3-dimensional model (densification, multi-technology, additional spectrum terms extended-DSA (eDSA)). Several technologies are implemented and managed to enhance spectrum availability in cooperation with multiple technologies to support capacity increase and service provision without impacting quality of experience, even improving it. SPEED-5G has developed innovative cloud-based architecture for ultra-dense networks based on a mix of centralized and decentralized resource management techniques. These coordinate a group of small cells so that interference can be managed based on opportunistic access on sub-6GHz spectrum resources with various licensing regimes. Small cells implement a multi-RAT MAC capable of resource management decisions on a local basis and efficiently steering traffic on these bands based on new waveforms such as filter bank multicarrier (FBMC). SPEED-5G has enriched specification of a hierarchical RRM/MAC framework and has implemented practical solutions to show the gain improvement in broadband traffic patterns. This has been integrated with HW/SW platforms on the project testbed, which embraces real-time MAC, wireless backhauling and virtualized resource management.



SPEED-5G Demonstration diagram with hierarchical RRM with entities located in the cloud (cRRM) and in the small cells (dRRM). dRRMs decide locally on spectrum utilisation, namely on the use of unlicensed spectrum. The local decisions are reported to cRRM entity, which can overrule a local decision if cRRM is aware of a possible interference situation. In this case, cRRM informs dRRMs about the spectrum utilisation to consider and small cells execute reconfigurations to apply the decision.
© SPEED-5G



Picture of the CEA-Leti's part of the SPEED-5G testbed, shown during the public event organised in BT's headquarters in London, UK. Video stream carried by the MAC/RRM blocks developed in CEA was demonstrated with an over-the-air transmission in the 5GHz WiFi channels. The channel selection was made by the machine-learning-based algorithm; good coexistence with BT's corporate WiFi has been demonstrated.
© SPEED-5G

IMPACT

The SPEED-5G project's major contribution represented by design, evaluation and implementation of a hierarchical protocol stack addressing centralized and decentralized RRM, MAC and physical layers has been able to optimize heterogeneous resources (e.g. spectra) in very dense networks. The project results have been promoted in multiple papers submitted to numerous standardization organizations (ETSI/RRM, 3GPP SA2, IEEE 1900.7 and IEEE 1932.1) and at a public event in March 2018.

Publications

• «Multi-RAT Dynamic Spectrum Access for 5G Heterogeneous Networks: The SPEED-5G Approach», I.-Pr.Belikaidis, A. Georgakopoulos, P. Demestichas, B.Miscopein, M. Filo, S. Vahid, B. Okyere, M. Fitch, IEEE Wireless Communications, vol. 24, no. 5, pp. 14-22, October 2017.
• «UNII-MAC protocol: Design and evaluation for 5G ultra-dense small cell networks operating in 5GHz unlicensed spectrum», R. El Chall, B.Miscopein, D. Kténas, ELSEVIER Comupter Communications, volume 126, pp. 11-27.
• «Trends and Challenges for Autonomic RRM and MAC Functionality for QoS Provision and Capacity Expansions in the Context of 5G Beyond 6GHz», I.-Pr. Belikaidis, A. Georgakopoulos, P. Demestichas, U. Herzog, Kl. Moessner, S. Vahid, M.Fitch, K. Briggs, B. Miscopein, in Proc. 2017 European Conference on Networks and Communications (EuCNC), Oulu, 12-15 June, 2017.
• «MAC Design for 5G Dense Networks Based on FBMC Modulation», R. El Chall, B. Miscopein, D. Kténas EAI Crowncom 2017 conference, Lisbon 2017.
• «TDD MAC protocol implementation for dynamic spectrum access in the 5 GHz band», J. Estavoyer and B. Miscopein, demonstration presented during the 25th International Conference on Telecommunications (ICT), ICT 2018, 26-28 June 2018, Saint-Malo, France.

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Benoit Miscopein
benoit.miscopein@cea.fr

Bernard Strée
bernard.stree@cea.fr



TOPAs

Tools for Continuous Building Performance Auditing

The TOPAs project is developing an open, Cloud-based platform of analytic tools for closing the gap between predicted and actual energy usage in buildings. The TOPAs is targeting a 10% reduction in the existing gap and aims to approach 20% additional energy savings in pilot regions.

https://www.topas-eeb.eu/

Keywords
Building energy performance gap
Energy usage continuous auditing
Energy usage prediction
Smart building
Stakeholder

TOPAs at a glance

36 months
Nov. 2015 > Oct. 2018

EC Programme
H2020 EeB-07-2015

Project Coordinator
Motorola Solutions Israel LTD (IL)

Partners
DE: Fraunhofer Institute for Solar Energy Systems (FHISE), Technische Universitäat Dresden
FR: Azimut Monitoring, CEA-Leti, EMBIX
IE: Cork Institute of Technology, Energy solutions, IBM Research

Total budget
€ 6.1 m.

EC Contribution
€ 5 m.

Contract Number
676760

Objectives

Building occupant behavior can be considered to be one of the main factors behind energy underperformance, hence TOPAs is focusing on reducing the difference from an operational perspective by supporting Post Occupancy Evaluation. Quantifying the performance gap is not trivial since it depends on time and contextual factors: different buildings exhibit different performance gaps.
Delivery of efficiency projects through energy performance contracts and Energy Service Companies (ESCOs) is widely seen as model methods of addressing sub-optimum post-installation performance of energy efficiency technologies. These models are very attractive from many standpoints and are seen as pertinent actions for delivering energy efficiency gains in the Energy Performance od Buildings Directive (EPBD). Methods and models for accurately measuring and verifying energy savings are therefore essential to ESCO market growth. The energy audit process is generally performed for a fixed period at a specific moment in time. A key outcome is identification and root cause analysis of energy inefficiencies before a derived plan is put in place to minimize these inefficiencies. This process can be very effective in curtailing a building's energy consumption. However, it can be difficult to identify all issues (in some cases conflicting system level goals) from an implementation standpoint and savings continuity can be poor, resulting in reappearance of inefficiencies. Continuous energy auditing extends this one-off process to set up a constant rolling cycle, in which a detailed overview of building performance is consistently available; this makes it possible to refine the energy management plan. The TOPAs project is adopting the principle of continuous performance auditing, in which it considers not only energy use, but also how the relevant building is used and its environmental conditions. It therefore offers a holistic performance audit process through its use of supporting tools and methodologies that contribute to minimizing the gap between predicted and actual energy use.

CEA-Leti in TOPAs

CEA-Leti has provided its LINC middleware, has collected data from sensors throughout buildings and has transferred them to an open Cloud platform. The Institute has also implemented control actions or references on building actuators, forwarded warning signals to building managers in the event of a problem and has retrieved helpful information on building control system status from the open Cloud platform.

CEA-Leti has proposed Indoor Air Quality indicators at office, zone, floor and building levels in order to monitor how the indoor environment evolves and send warning signals to building managers, when occupant comfort-related thresholds are crossed.

The institute has also developed a distributed control framework based on Model Predictive Control to control building temperature at office, zone and building levels based on occupant comfort and especially with regard to C02 concentration.

Lastly, CEA-Leti has implemented these tools and technologies on demonstration sites in France (Galeo building, Issy-les-Moulineaux) and Ireland (Nimbus and Melbourne buildings, Cork) and has coordinated the project partners at three demonstration sites in France (Issy-les-Moulineaux) and Ireland (Cork, Dublin) during the validation phase.



© TOPAs

IMPACT

TOPAS' major impact results from its long-term (several months), real-life demonstration of the set of tools developed during the project. It has also demonstrated the benefit of continuous energy auditing for reducing the gap between energy prediction and use.
Finally, LINC middleware has been used to deploy the control framework.

Publications

- *«Combining Transactional and Behavioural Reliability in Adaptive Middleware», A. Ndeye Sylla, M. Louvel, E. Rutten, 15th Workshop on Adaptive and Reflective Middleware, ARM 2016, Colocated with ACM/IFIP/USENIX Middleware 2016, Trento, Italy, 2016.*
- *«TOPAs, an IoT Driven Framework for Energy Efficiency in Buildings», S. Lesecq, M. Louvel, J. Ploennigs, S. Rea, N. Rehault, D. Wystrcil, A. McGibney, Sustainable Places, Middlesbrough, UK (Proceedings published by MDPI - open source), 2017.*
- *«Development tools for rule-based coordination programming in LINC», M. Louvel, Fr. Pacull, E. Rutten, A. Ndeye Sylla, International Conference on Coordination Languages and Models (Coordination 2017) - Lecture Notes in Computer Science, vol 10319. Springer, Cham, 2017.*
- *«Application of distributed model predictive approaches to temperature and CO_2 concentration control in buildings», Sh. Walker, W.Lombardi, S. Lesecq, S. Roshany-Yamchi, 20th World Congress of the International Federation of Automatic Control (IFAC 2017 World Congress), Toulouse, France, 2017.*
- *«Generating Models for Model Predictive Control in Buildings», Cl. Fauvel, Kr. Witheephanich, A. McGibney, S. Rea, S. Lesecq, Sustainable Places, Chambéry, France (Proceedings published by MDPI - open source), 2018.*

TRL
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Suzanne Lesecq
suzanne.lesecq@cea.fr

Dider Belot
didier.belot@cea.fr



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Wise-IoT

Worldwide Interoperability for Semantics IoT

The WISE-IoT project is addressing the issue of interoperability in today's Internet of Things (IoT) landscape, in which many emerging standards and proprietary solutions are creating isolated application silos with limited interactions. WISE-IoT is providing tools for rapidly building bridges between today's IoT protocols, thus enabling rapid integration of hardware and software solutions for multiple types of IoT application. The WISE-IoT approach has been tested in various European, Korean and cross-continental pilot cases in domains including smart city, smart healthcare and smart skiing.

http://wise-iot.eu

Keywords
Europe
Internet of Things (IoT)
Korea
Mediation gateways
Semantic interoperability
Smart city
Smart healthcare
Smart ski

Wise-IoT at a glance

24 months
Jun. 2016 > May 2018

EC Programme
H2020-EUK-2016

Project Coordinator
Easy Global Market (FR)
Sejong University (KR)

Partners
AT: CH: Fachhochschule Nordwesstchweiz
ES: Santander Municipality, University of Cantabria
FR: CEA-Leti, Institut Mines-Telecom, PIQ
GB: Liverpool John Moores University, NEC Europe
KR: Gangneung Science & Industry Promotion Agency, Gimpo Bigdata Co. Ltd., Ireis, KAIST, Korea Electronics Technology Institute, Kyungpook National University, Samsung SDS, SK Telecom, Solu M

Total budget
€ 3 m. (€ 1.5 m. EU + € 1.5 m.KR)

EC Contribution
€1.5 m. (+ € 1.5 m. contribution from Korean IITP)

Contract Number
723156

CEA-Leti in Wise-IoT

CEA-Leti is providing the WISE-IoT with its IoT sensiNact data collection and processing platform. This comprises a software platform enabling collection, processing and redistribution of IoT data relevant to enhancing people's quality of life via various applications from domains such as smart city, smart home, smart transport, etc. It provides programming interfaces allowing different data access methods (on-demand, periodic, historical, etc.) along with application development and deployment for easily and rapidly building innovative applications on top of the platform.

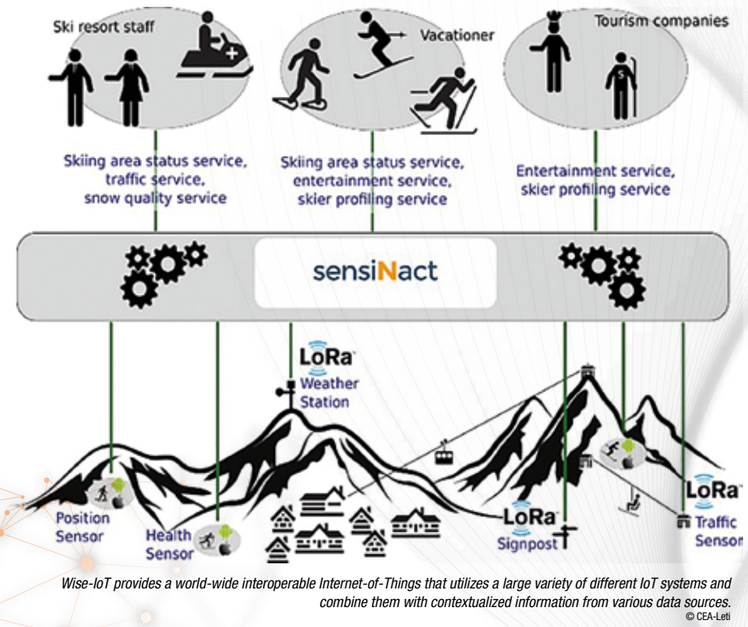
The WISE-IoT project allows sensiNact to interoperate with other European and Korean IoT platforms such as FIWARE, Mobius (open source OneM2M implementation) and Oliot (open source GS1 implementation) by creating specific adaptors for each platform.

CEA-Leti has been particularly involved in a smart ski use-case involving a skiing resort near Grenoble, France. The sensiNact platform is being used in a scenario, in which skiers are equipped with LORA connectivity-enabled sensors that measure the performance and location of skiers and offer them personalized recommendations. sensiNact is ensuring easy integration with other collected data involving detection of crowded areas, measurement of snow quality and level, detection of emergencies, etc. The platform allows data collected by the ski resort to be exploited for improving resource management.

Final simultaneous deployment of the smart ski use-case in France and South Korea was performed during the 2018 Winter Olympics in PyeongChang.

Objectives

The Internet of Things is addressing a multiplicity of still emergent standards and Alliance specifications through efforts to structure these into reference architectures. In this context, the WISE-IoT project has drawn together leading South European and Korean contributors to ongoing, major global IoT standardization to strengthen and expand emerging IoT standards and reference implementation using feedback from user-centric and context-aware pilots. Based on morphing the mediation gateways concept, a trust-based recommendation system is being proposed; this leverages Context Information APIs enabling end-to-end semantic interoperability and the dynamic distribution of analytic functions across proposed 'Global IoT Services' (GIoTS). These GIoTS provide IoT virtualization and interaction with systems beyond IoT, together with trust building and management capabilities.
Six European and South Korean testbeds have been federated to implement smart city, leisure and healthcare pilots that demonstrate GioTS-based application roaming capabilities across continents. An iterative development approach has been implemented to allow requirement and architecture adjustments as well as alignment and contributions to on-going standardization through submissions to technical committees and interoperability event support. A robust dissemination plan was drawn up and peaked during trials run at the 2018 Winter Olympic and Paralympic Games in PyeongChang.
The consortium composed of prestigious European and South Korean research institutes, SMEs and major industries have worked in tandem to contribute to the success of the Wise-IoT project. The WISE-IoT gave a particular attention to create an environment encouraging European and Korean SMEs and startups to enter the IoT industry by enabling access to a unified platform where interoperability among heterogeneous data in smart environments will be provided.



Wise-IoT provides a world-wide interoperable Internet-of-Things that utilizes a large variety of different IoT systems and combine them with contextualized information from various data sources.
© CEA-Leti

IMPACT

- Technical: laying the foundations of an interoperability framework in the IoT domain with reference implementations for protocols such as OneM2M, FIWARE and GS1
- Societal: improving citizens' quality of life in project pilot cities (Santander, Busan, Chamrousse ski resort, Grenoble)
- Economic: providing a cross-continental interoperable framework enabling European and South Korean SMEs to benefit from developed open source tools and establishing new relations with France's PACA and South Korea's Alpensia regions in the smart mountain domain.
- Global: strengthening global cooperation in the smart city domain by setting up the Urban Technology Alliance: www.urbantechnologyalliance.org.

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Levent Gürgen
levent.gurgen@cea.fr

Dider Belot
didier.belot@cea.fr

CYBERSECURITY

ACTIVAGE

M-Sec

PRISMACLOUD

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ACTIVAGE

ACTIVAGE PROJECT

https://www.activageproject.eu/
and **https://www.isere.fr/activage**

Keywords
Active and Healthy Ageing, Ageing well, Autonomy, Cybersecurity, General Data Protection Regulation (GDPR), Human centered design, Internet of Things, Interoperability, Large scale pilot, Smart home, Smart living

ACTIVAGE at a glance

42 months
Jan. 2017 > Jun. 2020

EC Programme
IoT- 01-2016: Large Scale Pilots

Project Coordinator
Medtronic Iberica SA (ES)

Partners
CH: CSEM
DE: Fraunhofer-IGD, IBM, WOQAZ
ES: Atenzia, Cruz Roja, Fondation Vodafone, Gestió Socio Sanitaria al Mediterrani (GESMED), HOPU, Initiativa social integral, Las Navas, Medtronic, MyShera, Sergas, Tecnalia, Televes, Universidad Politécnica de Madrid, Universitat Politècnica de València
FIN: eHOIVA, GoodLIFE, University of Turku
FR: CEA-Leti, Dépt de l'Isère, FBV Korian, Inter Mutuelles Assistance (IMA), IRT-Nanoelec, Madopa, STMicroelectronics, Technosens
GB: Leeds City Council, SAMSUNG, University of Surrey
GR: Center for Research and Technology Hellas (CERTH), CITIESNET, Gnomon, Institute of Communications and Computer Systems (ICCS), Infotrip, Municipality of Metamorfosis, Municipality of Pilea - Hortiatis
IR: National University of Ireland Galway (NUI Galway)
IT: Auroradomus sociale, Consiglio Nazionale delle Ricerche (CNR), CUP2000, Medea, Servizio Sanitario Regionale ER, University of Parma

Total budget
€ 25.1 m.

EC Contribution
€ 19.9 m.

Contract Number
732679

ACTivating InnoVative iot smart living environments for AGEing well

ACTIVAGE is a large scale experimentation project involving nine deployment sites in Europe; Its aims are to assess secured digital solutions to supporting and extending the independence of the elderly in their living environments and to respond to the real needs of caregivers, service providers and public authorities.

Objectives

ACTIVAGE is a European Multi Centric Large Scale Pilot project on Smart Living Environments. The main objective is to build the first European IoT ecosystem across nine Deployment Sites (DS) in seven European countries. This will reuse and scale up underlying open and proprietary IoT platforms, technologies and standards, and will integrate new interfaces for ensuring interoperability across these heterogeneous platforms. This will enable large scale deployment and operation of Active & Healthy Ageing IoT-based solutions and services, supporting and extending the independence of the elderly in their living environments, and responding to the real needs of caregivers, service providers and public authorities. The project will deliver the ACTIVAGE IoT Ecosystem Suite (AIOTES), a set of Techniques, Tools and Methodologies for interoperability at different layers between heterogeneous IoT Platforms and an open framework for providing semantic interoperability of IoT platforms for Active & Healthy Ageing (AHA), which addresses trustworthiness, privacy, data protection and security. User demand-driven, interoperable, IoT-enabled AHA solutions will be deployed in addition to the AIOTES at each DS to enhance and scale up existing services, promote independent living, mitigate frailty and preserve quality of life and autonomy. ACTIVAGE aims to assess the socio-economic impact, the benefits of IoT-based smart living environments in relation to quality of life and autonomy, and sustainability of the health and social care systems. It will demonstrate the seamless integration and interoperability capacity of the IoT ecosystem and will validate new business, financial and organizational models for care delivery, thereby ensuring post-project sustainability and disseminating its results worldwide. The project consortium includes industries, research centers, SMEs, service providers and public authorities encompassing the entire value chain at each deployment site.

CEA-Leti in ACTIVAGE

CEA-Leti-IRT Nanoelec composes the ACTIVAGE French Deployment Site (DS) based in France's Isère Department. DS Isère aims to create and evaluate a care continuum that combines human and technical assistance across different times in an elderly person's life to limit loss of autonomy and avoid unnecessary re-hospitalization.

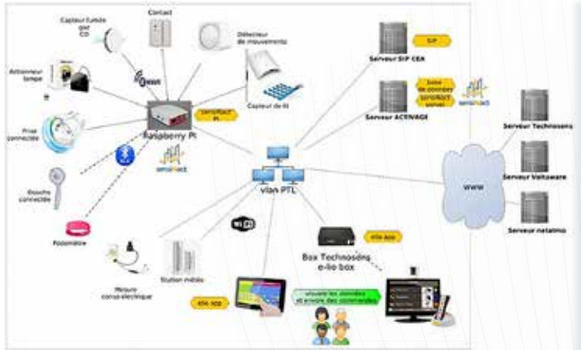
During the first year, CEA-Leti co-designed with all the project stakeholders IoT-based services to fulfil the requirements identified in different situations of the target elderly population. These designed solutions aim to enhance safety, comfort and social link to allow the elderly to remain independent at home for as long as they wish, to follow their evolving needs throughout ageing and to support caregiver intervention in detecting early signs of fragility.

During the second year, CEA-Leti developed a modular and adaptable IoT solution based on a Sensinact open IoT platform, wireless sensors and actuators. A secured gateway based on a STM secure element was prototyped. The modular solution was tested and refined on the IRT Nanoelec Testbed, which was adapted for ACTIVAGE. Three services were developed and will be assessed with three population panels, specifically Panel 1: Active Seniors (50 persons) and Panel 2: Fragile Elderly living at home supported by caregivers (20 persons) and Panel 3: Elderly Patient hospitalized in Korian Les Granges (10 rooms – 50 patients).

Regarding deployment, CEA-Leti is working with electrical tradesmen from third party Federation Française de Domotique (FFD). The Institute has trained five FFD electricians in preparing and installing the IoT solution.

Experimentation started early 2019 and is currently in ramp-up phase. A comprehensive process has been established in relation to inclusion, installation, support, maintenance and usage assessment. This process complies with GDPR regulations and the PIA (Privacy Impact Assessment) was prepared by CEA-Leti and the Isère Department.

Fifty homes for the elderly and three hospital rooms have been equipped since the end of June 2019 and more than 1000 IoT devices have been installed.



Smart home modular secure architecture.
© CEA-Leti



Electricians are trained to set up IoT kit at the IRt Nanoelec testbed.
© CEA-Leti

IMPACT

Initial feedback reveals the complexity of safely and securely commissioning heterogeneous home automation solutions and platforms in compliance with GDPR regulations. A secure infrastructure for monitoring units is key to exploiting the information provided by the devices. Continuing the work of IsèreADOM, the ACTIVAGE Isère DS will impact public policy, global care organization and digital tools via a step-by-step demonstrator.

Publications

- *«ACTIVAGE Secure Internet of Things Services for Ageing well: first deployment in Korian rehabilitation clinic», T. Loubier et al. ADTC 2018 5 European Nanoelectronics Applications, Design & Technology Conference) , Grenoble France, June 2018.*
- *"Indoor Occupancy Estimation via Location-Aware HMM: An IoT Approach", S. Kleisarchaki et al. IoT-SoS'18, (Internet of Things: Smart Objects and Services) Chania, Greece, May 2018.*
- *«End-to-end Security and Privacy by Design for AHA-IoT Applications and Services», M. Diaznav, M. Gallissot et al., in Cluster Book 2018 «Next Generation Internet of Things - Distributed Intelligence at the Edge and Human Machine-to-Machine Cooperation» River Publishers, November 2018 (ISBN: 9788770220088, e-ISBN - 9788770220071 - Open Access).*
- *«Continuum of Care that combines human and technical assistance : experience of the Isère Region, France», I. Chartier et al., Smart city Summit & Expo; Taipei- Taiwan, March 2019.*
- *«IoT for Smart Living Environments : Recommendations for healthy ageing solutions», O. Horbowy, I. Chartier, J. Fournier, B. Charrat et al., AIOTI WG05 "Smart Living Environments for Ageing Well", April 2019.*
- *«Real life experimentations of systems combining human and technical», A. Chambron et al.*

TRL
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Isabelle Chartier
isabelle.chartier@cea.fr

Bernard Strée
bernard.stree@cea.fr



M-Sec

Multi-layered Security technologies to ensure hyper connected smart cities with Blockchain, BigData, Cloud and IoT

The goal of the M-Sec project is to experiment smart city applications on top of cybersecurity devices to enable enhanced digital applications. Real use cases involving citizens will be deployed in cities of Santander in Europe and Fujisawa in Japan.

https://www.msecproject.eu/

Keywords
Blockchain
Cybersecurity
Internet of Things (IoT)
Smart-city

M-Sec at a glance

36 months
Jul. 2018 > Jun. 2021

EC Programme
H2020-EUJ-01-2018
Advanced technologies (Security/Cloud/IoT/BigData) for a hyperconnected society in the context of Smart City

Project Coordinator
ATOS Worldline (ES)

Partners
EL: Institute of Communication & Computer Systems / National Technical University of Athens
ES: Ayuntamiento de Santander, Tecnologías Servicios Telemáticos y Sistemas
FR: CEA-Leti
IE: F6S
JP: National Institute of Informatics, NTT Data Institute of Management Consulting, NTT East Corporation Keio University, Waseda University, Yokohama National University

Total budget
€ 1.5 m.

EC Contribution
€ 1.5 m.

Contract Number
814917

CEA-Leti in M-Sec

In this project, CEA-Leti provides cybersecurity functions for the IoT devices and gateways and provides the Sensinact middleware to enable secured applications to be developed on top of the secured devices. These assets are integrated into the different use cases and are interfaced with the other partners' assets.

Device and gateway security is ensured with project partner TST, which provides IoT sensors with WAN connectivity. These sensors have no on-board security and are must be combined with secure components, on which secured functions are performed. Key challenges reside in the efficiency of the solution and robustness to the security scheme. The secure component ensures the integrity of the IoT node with respect to firmware and software and is also used to authenticate the device for its network. Finally, it stores any sensitive information for communication encryption to the M-Sec cloud.

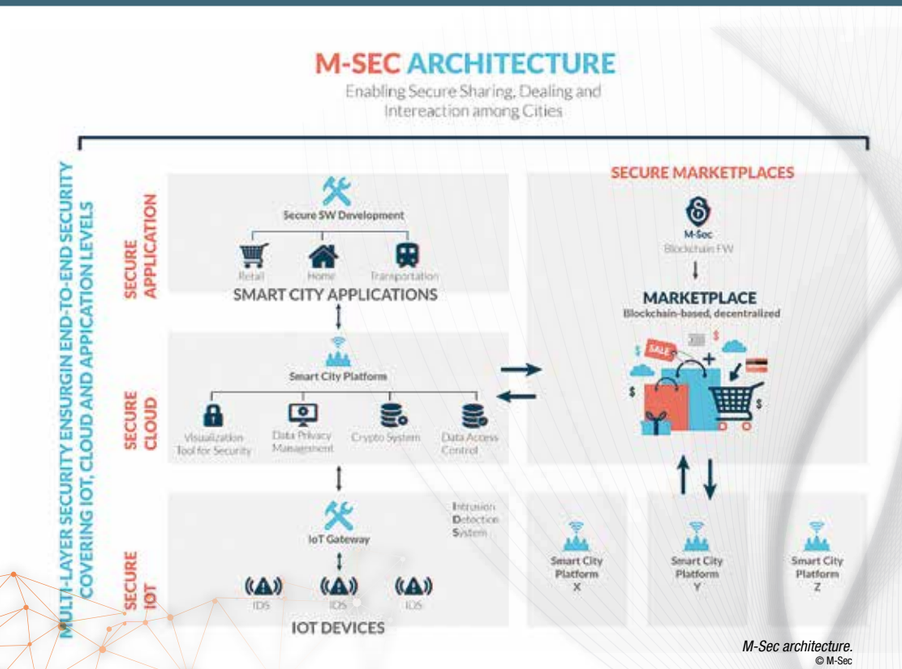
Gateway and cloud applications are secured on the software level with accountability and rights management on a per-resource basis in the Sensinact middleware. This enforces the privacy and confidentiality across applications and services in smart city use cases in which trust is an interoperability enabler. Sensinact's studio is used for developing secured applications in a friendly way and makes smart applications auditable. Finally, Sensinact's middleware will be the interface for the blockchain-based marketplace.

Objectives are to reach a level of trust for a full secured stack spanning from devices to a marketplace developed by partners based on blockchain technology.

Objectives

Internet of Things (IoT) systems today tend to be built around the concept of IoT/cloud convergence, integrating heterogeneous data streams within cloud infrastructures and thus benefitting from the scalability, performance and capacity of the cloud. This approach is very efficient for certain IoT applications such as those applicable to big data processing. However, these architectures promote a centralized data collection and processing approach, which introduces several limitations in terms of the supported applications and business models they enable.
The main goal of M-Sec project is to empower IoT stakeholders to develop, deploy and operate novel IoT applications based on a scalable highly decentralized paradigm, which facilitates incentivized peer-to-peer interactions between objects and people. Based on a defined social context, the project explores semantically interoperable interactions between people and objects beyond simple peer-to-peer information exchange and internetworking. Overall, the M-Sec paradigm will enable introduction and implementation of specific classes of applications and services that are not efficiently supported by state-of-the-art architectures. The M-Sec project will deliver a set of main concrete, added value results:

- M-Sec distributed, self-organized, robust and trusted IoT infrastructure that empowers IoT stakeholders to develop, deploy and operate novel multipurpose IoT applications for smart cities on top of smart objects
- An open IoT market of applications, data and services that provides the framework upon which objects and people can exchange value and defines the motivation incentives for humans and smart objects to interact
- A sustainable ecosystem of stakeholders, roles, tools and infrastructures upon which new entrants and other players can build and experiment with the future application services
- A parameterized model enabling further replication of the M-Sec approach and guaranteed return on investment and benefits.



M-Sec architecture.
© M-Sec

IMPACT

The impact of the M-Sec project is its development of a secured, trustworthy IoT and Big Data framework for smart cities. This framework provides integrated security and privacy technologies to ensure full compliance with regulations applicable in Europe and Japan such as privacy regulations (GDPR, PIPA), data portability and free flow. The framework is expected to be a candidate for standardization.

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Mathieu Gallissot
mathieu.gallissot@cea.fr

Bernard Strée
bernard.stree@cea.fr



PRISMACLOUD

Privacy and Security Maintaining Services in the Cloud

The PRISMACLOUD project is dedicated to enabling secure, trustworthy cloud-based services by improving and adopting novel tools developed from cryptographic research. The project brings novel cryptographic concepts and methods to practical application and makes them usable for providers and users.

prisma cloud

https://www.prismacloud.eu/

Keywords
Cloud computing
Confidentiality
Privacy
Security
Signature

PRISMACLOUD at a glance

42 months
Feb. 2015 - Aug. 2018

EC Programme
H2020

Project Coordinator
Austrian Institute of Technology (AT)

Partners
AT: Austrian Institute of Technology, Graz University of Technology, XiTrust Secure Technologies Gmbh
CH: Université de Lausanne
DE: MikroPlan Gmgh, Technische Universität Darmstadt, Universität Passau
FR: CEA-Leti
ES: ATOS Spain, ETRA Investigacion y Desarrollo S.A.
IL: IBM Israel Science & Technology Ltd
IT: Fondazione Centro San Raffaele, Interoute S.p.a., Lombardia Informatica S.p.a.
SE: Karlstad University
UK: University of Newcastle upon Tyne

Total budget
€ 8.4 m.

EC Contribution
€ 8.0 m.

Contract Number
644692

Objectives

Today, cloud computing is already widely used and is starting to enter every sphere of our lives including both private and business areas. PRISMACLOUD project goals have been identified to address challenges and enable implementation of services with intended security characteristics.

These goals include in particular:
- Development of cryptographic tools to protect security of data during its lifecycle in the cloud
- Development of cryptographic tools and methods to protect user privacy
- Creation of enabling technologies for cloud infrastructures
- Development of a methodology for secure service composition
- Experimental evaluation and validation of project results.

CEA-Leti has focused on developing a hardware crypto accelerator for post-quantic signature algorithms and on evaluating and strengthening this design against side channel attacks. It has achieved and demonstrated a proof of concept for a post-quantum redactable signature scheme using this hardware block.

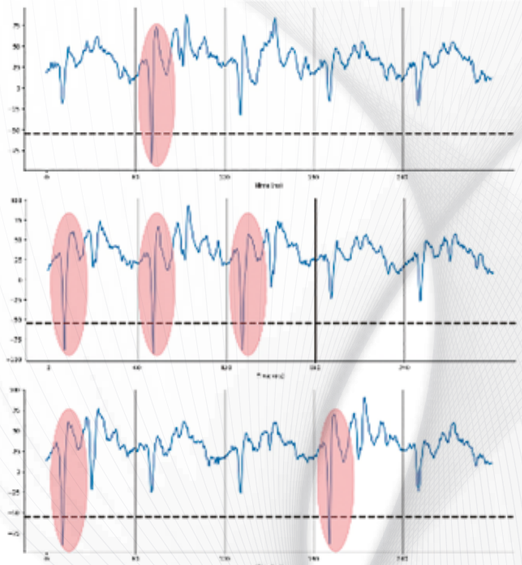
CEA-Leti in PRISMACLOUD

- CEA-Leti has performed risk analyses on a number of pilot use cases set-up to showcase the benefit of new cryptographic tools developed within the project.
- CEA-Leti has evaluated the sensitivity of cryptographic primitives developed in the project to physical attack (side-channel and fault injection). This helps in early identification of critical portions of these algorithms that require special care for a secure implementation. Insertion of appropriate countermeasures may now be considered at the earliest moment, when drafting implementation specifications.
- CEA-Leti has implemented a redactable signature scheme that is robust to attacks implemented over quantum computers. This redactable scheme will serve as a selective disclosure component that could be used in the e-health or smart-cities use cases. The redactable signature schemes use a conventional signature scheme as a core component but are vulnerable to attacks, based on Shor's algorithm, implemented over a quantum computer. The post-quantum resistance requirement has led to selection of a different technology, specifically lattice-based cryptography. The state of the art regarding implementation of lattice-based signature schemes has therefore been reviewed to choose the most efficient algorithm to be integrated in the project redactable scheme. The Bimodal Lattice Signature Scheme (BLISS) was eventually chosen; this is efficient, sufficiently mature and supported by the SAFECrypto project (ICT-644729, http://www.safecrypto.eu/).
- The hardware implementation of a redactable signature scheme has targeted provision of tamper resistance and high speed. Even a correct hardware implementation of a strong cryptographic algorithm is not necessarily secure since information about the secret key may leak through physical measurements such as power consumption, electromagnetic radiations or operation timing. This vulnerability has led to many so-called side channel attacks. However, countermeasures have also been proposed in the literature to defeat these attacks. CEA-Leti's hardware specifications must take into account the main attacks and incorporate adequate countermeasures so specific countermeasures dedicated to the main modules of BLISS (e.g. NTT, Gaussian sampler) have been identified.
- Hardware implementation has been evaluated with respect to side channel attacks using electro-magnetic measurement analysis. A path to secret key recovery has been found and the attack has been successfully demonstrated. In view of this vulnerability, an improved implementation version has been tested and has proved resistant to attack. Finally, the hardware has been used to demonstrate a post-quantum redactable signature scheme.

S1 = 0 -1 1 0 0 ...
S2 = 0 -2 -2 0 0 ...

S1 = -1 -1 -1 0 1 ...
S2 = 2 -2 0 0 0 ...

S1 = -1 0 1 -1 0 ...
S2 = 2 2 2 -2 0 ...



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IMPACT

PRISMACLOUD has increased European technical knowhow and more specifically:
- Verifiability of data and infrastructure use: protecting computation results (maintain authenticity, enable verifiability) and enabling methods for infrastructure attestation
- User privacy enhancing technologies through data minimization anonymization
- Securing of data at rest through secure distributed information sharing, long-term security and structured data security.

TRL
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Alain Chambron
alain.chambron@cea.fr

Bernard Strée
bernard.stree@cea.fr

IMAGE & VISION

HELIAUS
HOLDON
PEROXIS
SWIR-UP
VOSTARS

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HELIAUS

Heliaus

https://www.heliaus.eu/

Keywords
Autonomous driving applications
Embedded systems
Machine learning
Smart thermal vision systems

HELIAUS at a glance

36 months
Avr. 2019 > Mar. 2022

EC Programme
H2020-ECSEL-2018-2-RIA-two-stage

Project Coordinator
LYNRED (FR)

Partners
DE: DENSO ADAS Engineering Services GmbH, Fraunhofer IPT
FR: Another Brain, CEA-Leti, CNRS, ONERA, LYNRED, Umicore
IE: XPERI Limited, National University of Ireland Galway
IT: Next2U s.r.l.

Total budget
€ 28.2 m.

EC Contribution
€ 0.8 m.

Contract Number
826131

Thermal Vision Augmented Awareness

The aim of the HELIAUS project is to develop a reliable system that upgrades existing perception systems (incorporating only visible imaging, LIDAR and RADAR detection) by adding thermal vision inside and outside the vehicle passenger compartment in all light and weather conditions.

Objectives

Within the scope of Smart Mobility, anticipated vehicle driving practices and usages require reliable, affordable and versatile perception systems, which must be accurate and reliable in relation to events inside and outside the vehicle passenger compartment. Monitoring of the vehicle's driver, passengers and its surrounding environment in all light and weather conditions must be improved and today's perception systems (based mainly on visible imaging, LIDAR and RADAR detection) must be upgraded to include thermal sensing. The latter technology, especially in the LWIR (6 - 14 µm) bandwidth, provides valuable additional information and is considered essential to the next generation of L4 (''Eyes off'') and L5 (''Mind off'') autonomous driving systems.
In this context, the HELIAUS project will deliver breakthrough perception systems for monitoring the vehicle's driver, passengers and surrounding environment based on smart thermal sensing. These novel perception systems will extend current technology to include operation in the LWIR bandwidth.
The overall objectives of the HELIAUS project are to:

1/ Develop cutting edge, cost effective technologies leading to cheap, high-performance LWIR modules
2/ Specify, develop, test and validate first prototypes of thermal perception systems operating inside and outside the passenger compartment
3/ Quantify thermal sensing's valuable addition to the current and future systems
4/ Promote the benefit of such systems for smart mobility and, in particular, for future autonomous vehicles.

The HELIAUS project is a first and essential step towards building cheap, industrialized thermal perception systems. The project is contributing to global competitiveness of European industry since it forms part of IPCEI Microelectronics, in which LYNRED is leading a «Smart Sensors»-based project.

CEA-Leti in HELIAUS

CEA-Leti objectives two years hence:

• Validation of an innovative microelectronic process underlying the used of foundry-compatible equipment and processes for a high-performance infrared microbolometer.
This work is prompting:
- Design of a new pixel architecture
- Assembly of a new pixel process

• Assessment of the advantage of new LWIR thermal systems by integrating novel IR sensors into camera modules with embedded processing, which includes:
- Development and implementation of conventional machine learning techniques and new neuro-based classifiers

• Application-related appraisal of the advantages and limitations of IR thermal sensors compared with other sensor technologies especially LIDAR and RADAR

• Feedback on possible development of IR thermal sensors for enhancing complementarity with other sensor technologies to ensure safer environmental perception

• Improvement of existing CEA 3D detection algorithms by incorporating 2D IR thermal imaging as an additional data source.



© Heliaus

IMPACT

HELIAUS' technological and scientific impacts result from creation of know-how in IR microbolometer fabrication and development of innovative IR smart modules.

The project's application impact results from vehicle passenger compartment and surrounding environment perception developments and assessments, and availability of a cheap, high-performance IR module with embedded processing. Large volumes of the latter unit can be produced in Europe and integrated into vehicles to ensure safer transport and smart mobility, thereby reducing road accidents and casualties.

TRL
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Patrick Leduc
patrick.leduc@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr



HOLDON

HgCdTe APD Optimization for Lidar Detection Of greeNhouse gas

The HOLDON project aim is to develop a highly sensitive LIDAR detector module for atmospheric surveillance of greenhouse gases (CO2, CH4). This detector will be assessed in relation to its potential capacity for integration into mini-satellites for future operation.

www.holdon-h2020.eu

Keywords
Avalanche photoDiode
CMOS
Detection module
DIAL
Earth observation
Greenhouse gases
Global warming
High dynamic range
LIDAR
PDA
Photon-counting
Readout circuit
Technology for space

HOLDON at a glance

48 months
Jan. 2018 > Jun. 2021

EC Programme
H2020-space-compet -2017

Project Coordinator
CEA-Leti (FR)

Partners
CH: IDQuantique
DE: Deutsches Zentrum für Luft- und Raumfahrt
ES: Alter Technology
FR: Absiskey, Airbus Defence and Space, Ecole Polytechnique / Laboratoire de Météorologie Dynamique

Total budget
€ 2.5 m.

EC Contribution
€ 2.5 m.

Contract Number
776390

Objectives

LIDAR remote sensing of the Earth's atmosphere is a key tool for monitoring the effects and causes of global warming caused by greenhouse gas emission. LIDAR is the acronym of «Light Imaging, Detection and Ranging». It refers to a surveying method that measures distance to a target by illuminating the latter with pulsed laser light and measuring the reflected pulses with a sensor. With regard to atmospheric monitoring, today's LIDAR applications are all installed at large satellite platforms because of the size of the telescope and high energy laser modules required to ensure sufficient light intake and separate the return signal from detector noise. The purpose of the HOLDON project is to develop a new, versatile detection chain, which will improve LIDAR performance, and to reduce LIDAR payload for future mini-satellites. Increased performance is obtained by optimizing high quantum-efficiency HgCdTe Avalanche PhotoDiodes (APD) to be hybridized to a specially designed CMOS readout circuit (ROIC) offering two operating modes. The devices are expected to meet the most stringent specifications for LIDAR applications implementing ultra-violet to near-infrared wavelengths in terms of sensitivity, dynamic range and temporal resolution (high dynamic range down to single photon sensitivity). Seven European partners (CEA-Leti, DLR, AIRBUS, IDQ, LMD, ALTER and ABSISKEY) are cooperating to take up the following three challenges:

- Design and manufacturing of a cutting edge, photon noise-limited LIDAR detection chain
- Demonstration of the improvement achieved with the detection chain for greenhouse gas detection (especially CO2 and CH4)
- Validation of the adequacy between LIDAR detection key performance characteristics and future space mission requirements.

CEA-Leti in HOLDON

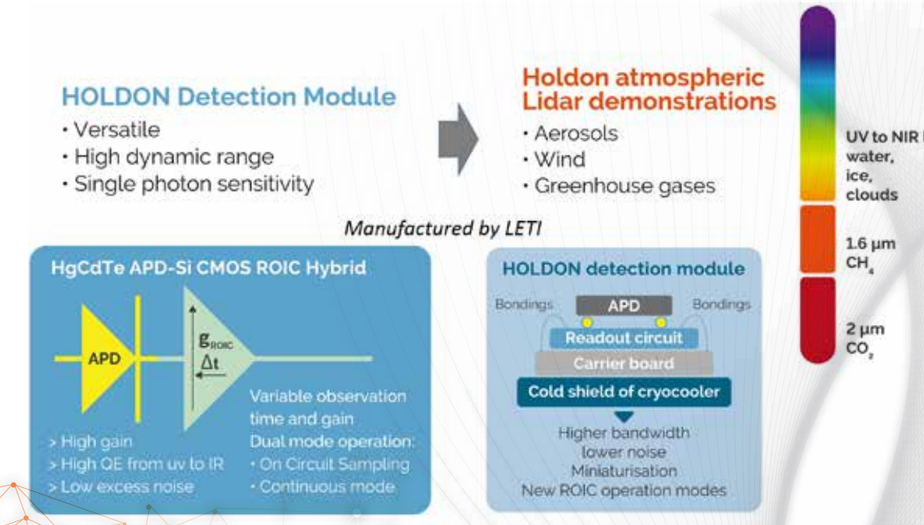
- CEA-Leti is manufacturing the detection module to be integrated into the full LIDAR chain. During the first year of project, **CEA-Leti and its technical partners drew up the full specifications for the HOLDON detector** (APD, ROIC, optical and electronic interfaces) specifically for greenhouse gases and LIDAR altimetric measurements. These specifications were validated after analyzing relevant space and ground atmospheric LIDAR scenarios for 350 nm to 2 µm wavelengths embracing **a wide dynamic range between 10^6 and 10^12 photons/s** for limited signal detection of a shot noise.

- CEA-Leti has now launched development of the detector module technological bricks, which will be based on **HgCdTe APDs hybridized with specifically designed CMOS ROIC. The combination will be packaged in a cryo-cooler).** HgCdTe APDs have the unique advantage of combining high quantum efficiency over a broad spectral window with a close to deterministic avalanche gain, which allows amplification of the signal to a level higher than the electronic amplifier noise with almost negligible information loss.

- Regarding the specifications, CEA-Leti has studied different potential ROIC architectures and conducted simulation campaigns. **The ROIC architecture has now been frozen, offering a dual operation mode** with different possible gains covering the required wide dynamic range. The two modes are continuous for conventional sampling on proximity electronics or switchable **on-chip-sampling** with variable observation time, gain and accumulation capabilities.

- **CEA-Leti has defined the APD architecture** and the mask set specifications for the technological process of forthcoming batches and **has undertaken epitaxial growth of the high quality HgCdTe layers.**

- The APD performance characteristics will be optionally maximized, while minimizing response time and dark current, by optimizing optical coupling to the APD with **micro-lenses**, which will be directly machined on the side of the APD chips, which will be illuminated by the laser echo.



Schematic view of the HOLDON lidar module in development at CEA-Leti.
© CEA-Leti

IMPACT

The ambitious specifications for the HOLDON LIDAR module outperform the state of the art. We expect to foster scientific excellence in Europe, in particular by maintaining Europe's leadership in the physics and applications of HgCdTe APDs and by enabling new cooperations. Furthermore, a versatile detection chain offering low payload will pave the way towards a European commercial offer for atmospheric and space LIDAR applications fulfilling similar needs and potential industrial exploitation by a number of interested companies.

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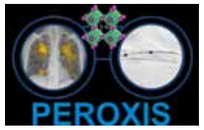
Jérôme Le Perchec
jerome.le-perchec@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr

Pierre Castelein
pierre.castelein@cea.fr



PEROXIS



Keywords
CardioVascular Disease (CVD)
Chronic Obstructive Pulmonary Disease (COPD)
Direct conversion
Phase contrast imaging
Perovskite
X-ray imaging

PEROXIS at a glance

36 months
Jan. 2020 > Dec. 2022

EC Programme
ICT-05-2019 RIA-ii

Project Coordinator
CEA (FR)

Partners
DE: Siemens Healthineers
ES: Universitat Jaume I
FR: CEA, CNRS, Trixell
NL: Philips, TNO

Total budget
€ 5.9 m.

EC Contribution
€ 5.9 m.

Contract Number
871336

Ground-breaking PEROvskite technologies for advanced X-ray medical Imaging Systems (PEROXIS)

The aim of the PEROXIS project is to develop a new X-ray imaging system offering greater sensitivity and spatial resolution than existing conventional systems to facilitate diagnosis, while reducing the dose received by the patient during a radiological examination.

CEA-Leti in PEROXIS

The PEROXIS project is investigating two disruptive, cost-effective approaches to integrating efficient , scalable, thick perovskite conversion layers with appropriate properties for X-ray direct detection purposes.

• The first approach is based on a powder sintering process for applying a microcrystalline MAPI layer to an active matrix surface.

• In cooperation with CNRS (Neel Institute), CEA-Leti is in charge of a second **approach based on a solution process for growing in-situ a dense, highly crystalline, MAPbBr3 layer directly on the active matrix.**
The PEROXIS project is prompting CEA to develop a groundbreaking, 2-step (seeding and growing) process for in-situ, solution-based growth of perovskite from the active matrix surface.

• Improved layer quality and homogeneity is obtained by using a specific set-up to grow the perovskite from solution to give higher quality polycrystalline layers.
> Selection of best surface preparation for seeding (M18).

• The groundbreaking, solution process approach has been demonstrated on 5×5cm² X-ray detectors.
> Fabrication and testing of an X-ray detector using the solution process approach (M30) to demonstrate higher efficiency and spatial resolution performance.
This solution process ensures better detector efficiency and dynamic response, and reduced memory effect (image lag and ghosting). These performance improvements allow the perovskite-based detector **to perform X-ray spectral imaging and to open up the way to an upcoming radiographic breakthrough.**

Objectives

The PEROXIS project is developing a new X-ray imaging system offering greater sensitivity and spatial resolution than conventional systems to facilitate diagnosis during patient examination and treatment of various diseases.
Emerging semiconducting perovskite materials, widely used for photovoltaic applications, are good candidates since they have the potential to address globally the following ambitious objectives:
• Advancing X-ray-based imaging systems for advanced diagnosis and treatment of cardiovascular disease (CVD) and chronic obstructive pulmonary disease (COPD)
• Improving the efficiency and spatial resolution of flat panel X-ray detectors
• Producing groundbreaking, perovskite-based, direct conversion, X-ray imaging detectors for large-area compatibility
• Validating the feasibility of phase contrast imaging for earlier detection of chronic obstructive pulmonary disease.
PEROXIS is a multidisciplinary project involving seven partners from four EU countries (France, Germany, Spain and the Netherlands) spanning academic, RTO and industrial (three major medical equipment manufacturers) worlds. An implementation plan has been presented in the form of eight work packages, six of which are technical. The communication and dissemination synergy ensured by the partners and stakeholders (external advisory board mainly composed of physicians providing letters of intent) maximizes the PEROXIS project impact.
Solutions have been presented for overcoming fundamental technological barriers and relevant deliverables, tasks, milestones and risks involved in timely fulfilment of the PEROXIS project aims. The project outcome should have a strong impact on the medical sector: future applications of an improved PEROXIS imaging system will not be limited to COPD and CVD, but should extend to other clinical domains, in which performance of diagnosis-driven therapy systems is currently limited by flat panel X-ray detector technology.



IMPACT

PEROXIS consortium industrial partners Siemens and Philips are the numbers one and three in diagnostic imaging market. Trixell will be the partner that will take up and industrialize the new technology developed in this project, while Philips and Siemens are the perfect candidates for commercializing the technology and delivering it into the medical imaging market. The intention is to keep detector prices at levels appropriate to the different potential markets. This will foster development of novel, higher performance products inspired by the PEROXIS project solutions, thereby ensuring a major impact on a number of diseases and promoting Europe's leadership in high-value markets.
The PEROXIS project partners will initially consider cardiovascular diseases (CVDs), which represent the leading cause of death globally, and respiratory diseases, especially chronic obstructive pulmonary disease (COPD), which is the third leading cause of death worldwide. Extension to other diseases will also be considered. The PEROXIS project is essential to safeguarding and expanding Europe's market position in the face of upcoming Asian competition. The partners' plans for exploiting PEROXIS' developments (potential for new patents, products, spin-offs, etc.) will be updated during the project to generate major impact on a range of diseases and greater competitiveness.

TRL
1 2 3 **4** **5** 6 7 8 9

Jean-Michel Casagrande
jean-michel.casagrande@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr


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SWIR-UP

HOT III-V & II-VI Focal Plane Arrays for Space Applications in the Upper SWIR Band

Shortwave infrared image sensors complement visible light image sensors in high-resolution Earth observation missions (e.g. vegetation/greenhouse gas monitoring). The SWIR-UP project is developing image sensors that do not require cryogenic cooling, thereby achieving miniaturization and reduced satellite power consumption.

https://swirup.eu/

Keywords
III-V and II-VI detector technologies
HgCdTe P/N, HOT SWIR focal plane array
InGaAs /GaAsSb Type-II super-lattice
Remote sensing instruments & sensors
Satellite earth observation
Technology for space

SWIR-UP at a glance

42 months
Jun. 2018 > Nov. 2021

EC Programme
H2020 Space –compet 17

Project Coordinator
Thales Alenia Space (FR)

Partners
FR: III-V Lab, CEA-Leti, Thales Alenia Space
NO: Norsk Elektro Optikk AS
UK: Rutherford Appleton Laboratory, University of Sheffield

Total budget
€ 2.8 m.

EC Contribution
€ 2.8 m.

Contract Number
776278

Objectives

Space missions performing high-resolution Earth observation (including greenhouse gas monitoring) require optical sensors covering both visible channels and the Short Wavelength Infra-Red (SWIR) band. With regard to SWIR optical sensors, the current approach in Europe has been implementation of HgCdTe N/P sensors cooled to cryogenic temperature.
SWIR-UP is an H2020 project, whose goal is to develop an alternative photosensitive material to those used in today's HgCdTe N/P sensors. It is focusing on «III-V»: a material comprising an InGaAs/GaAsSb super-lattice matched to an InP substrate.
The primary objective of the project is to extend the cut-off wavelength (currently limited to 1.7 µm for off-the-shelf detectors operating at room temperature) to 2.5 µm by adding additional SWIR bands to the visible channels commonly used by instruments dedicated to Earth observation from space. SWIR-UP sensor technologies also offer alternatives to HgCdTe N/P detectors for commercial applications in the SWIR spectral range. These include hyperspectral imaging systems (for airborne, field, laboratory and industrial applications) and Lidar (for active imaging applications).
A secondary objective is to achieve higher operating temperatures for focal plane arrays: allowing operation as close as possible to room temperature (230-290 K) compared with typically 200-210 K for today's HgCdTe detectors. This eliminates cryogenic cooling to improve the miniaturization, power reduction, efficiency and versatility of optical payloads, all of which could offer opportunities for greater functionality.
With in the scope of this action, new SWIR-UP technology is also being compared to current reference II-VI technology embodied by HgCdTe P/N material. This should lead to a technological prioritization based on application type since each material has specific advantages. "II-VI" material, already optimized for cooled astronomical application, is being upgraded for operation at higher temperatures.
The SWIR-UP project also involves manufacturing and testing 2D arrays (640 x 512, 15 µm pitch, cut-off wavelength approximately 2.5 µm) with a sensing module based on both III-V and II-VI technologies. Reaching TRL5 at the end of the project, the best performing technology will enter the industrialization phase and be commercially integrated around 2022.

CEA-Leti in SWIR-UP

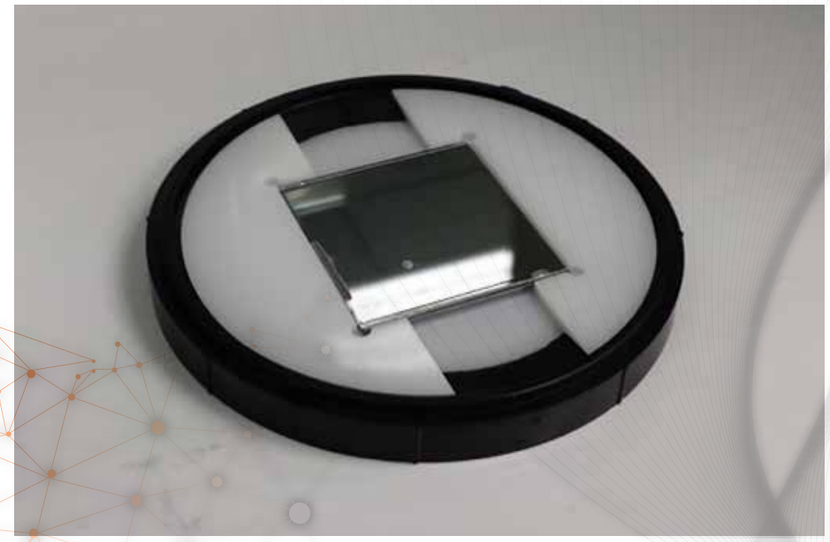
In SWIR-UP, CEA-Leti is upgrading p/n HgCdTe photodiode technology, which has already been matured for low operating temperatures at SOFRADIR, an industrial partner in infrared imagery for over 25 years. Revision of the design of the epilayers and p/n photodiode has enabled CEA-Leti to achieve a new state of the art at higher operating temperatures. This work serves as a reference for the new extended InGaAs technology also developed in the project. Adjusted epilayers have been grown and will be processed to fabricate 2D photodiode arrays (TV format, 15 µm pitch). The cut-off wavelength is around 2.45 µm.

CEA-Leti is also using its longstanding expertise in cooled imaging sensor fabrication and characterization to:

• Hybridize the 2D HgCdTe and extended InGaAs detector arrays on existing read-out integrated circuits supplied by SOFRADIR

• Participate in packaging of the resulting focal plane arrays onto fan-out ceramics to be installed in a specifically designed cryostat

• Permit initial comparison of the electro-optical performance characteristics of HgCdTe and extended InGaAs photodiode technologies in terms of dark current, noise, quantum efficiency, response and operability. Particular emphasis will be placed on the level of dark current with respect to the operating temperature since as this important value is key to avoiding cryogenic cooling.



HgDGte based photosensitive material optimized for détection in SWIR band.
© CEA-Leti

IMPACT

The SWIR-UP project is directly expanding the Earth observation technology portfolio to ensure Europe's leadership in SWIR imaging at very low power consumption. The project will impact many other markets: military, civilian and professional (hyperspectral imaging, scientific imaging, machine vision, etc.).

TRL
1 2 **3** **4** **5** 6 7 8 9

Pierre Castelein
pierre.castelein@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr

Roch Espiau de Lamaestre
roch.espiau-de-lamaestre@cea.fr


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VOSTARS

VOSTARS

http://www.vostars.eu/

Keywords
Augmented reality
Microdisplays
Optical sensors
Photonics
Surgical guidance
Wearable head mounted display

VOSTARS at a glance

42 months
Jan. 2017 > May 2020

EC Programme
H2020-ICT-29-2016

Project Coordinator
Universita de Pisa (IT)

Partners
FR: Optinvent
GB: Vreo Innovation
GE: Charité-Universitätsmedizin Berlin, Pilotfish, Sankt Gertrauden-Krankenhaus GmbH, TU Munich
IT: Mectron, Orhtokey, University of Bologna, University of Pisa

Total budget
€ 4.4 m.

EC Contribution
€ 3.8 m.

Contract Number
731974

Video Optical See-Through Augmented Reality surgical System

The VOSTARS project aims to assist surgeons in medical procedures by providing them with gestural guidance through smart eyeglasses. During surgery, physicians are using remote displays, on which they can view the patient live and a number of augmented reality-based, guiding lines to assist them in their gestures. The VOSTARS concept is prompting development of innovative, augmented reality, smart eyeglasses that allow the surgeon to focus on the patient, while benefitting from the guiding line support displayed by the smart glasses. The greatest challenge is to fit the guiding line into the real scene in real time.

Objectives

The idea of enhancing the surgeon's perceptive efficiency with new Augmented Reality (AR) viewing methods has been a dominant topic of academic and industrial research in the medical field since the 1990s. AR technology would represent a significant development with the field of Image-Guided Surgery (IGS).
The quality of the AR experience affects its degree of acceptance among surgeons; much depends on how well the virtual content is integrated into the real world spatially, photometrically and temporally. In this regard, wearable systems based on Head-Mounted Displays (HMDs) offer the most ergonomic and easily translatable solution for many surgeries.
Most AR HMDs fall into two categories - Video See-Through (VST) and Optical See-Through (OST) - according to the see-through paradigm they implement. In OST systems, the user's direct view of the real world is augmented with the projection of virtual information into the user's line of sight. In VST systems on the other hand, the virtual content is merged with images captured by two external cameras anchored to the visor. With respect to technological and human-factor issues, both approaches have their advantages and drawbacks. In a hybrid OST/VST HMD, the VOSTARS project has identified a disruptive solution for improving surgical outcomes. In the last two years, the hybrid HMD has been developed in close cooperation with surgeons and design work has been dedicated to specific application. Off-the-shelf components and innovative displays have been embedded and an innovative calibration procedure allows the system to react virtually in real time. Final technical details are now being finalized before testing the system in clinical trials, whose results will be fundamental to immediate industrial uptake based on economic viability analysis.

CEA-Leti in VOSTARS

CEA-Leti is contributing the Key Enabling Technology (KET) to the VOSTARS proposal. Since 2013, CEA-Leti has been developing new GaN microLED display technology, which offers advantages over standard OLED, LCOS or LCD display technology, including super high brightness (> 1 million cd/m² on a passive matrix) and lower consumption, because it is emissive technology. During the VOSTARS project, CEA-Leti has modified OLED active matrices to make them compatible with the GaN microLED process. GaN pixellization has been achieved, while microtubes have been processed on the CMOS wafer. The two parts were then aligned and bonded together to obtain a 853 x 500 pixel microLED display. Specific IC boards have been designed to pilot the display, while post-process correction has been required to correct LED driving and expand the image grey scale. Green epitaxy was chosen for greater brightness: 3000cd/m² has been achieved. Limited brightness is due to a non-dedicated ASIC, but the project scope does not include developing a dedicated ASIC. However, the former did contribute ensure progress in the technological field and allowed us to integrate a GaN-based display into an Optinvent wave guide optical module.



Image seen through the Optinvent optical module showing the green microdisplay developed by CEA-Leti.
© CEA-Leti

IMPACT

Augmented Reality is a very promising research and development area and surgeons, who already use such technology, are excellent candidates for assessing a new HMD model. CEA-Leti wishes to extend its work on system applications and VOSTARS is a fine project and platform for meeting systems specialists. Moreover, this project has offered CEA-Leti the opportunity to embed its state-of-the-art microLED display in a full HMD system.

Publications

- *«Green InGaN/GaN based LEDs: high luminance and blue shift», A. Daami, F. Olivier, L. Dupré, C. Licitra, F. Henry, F. Templier, S. Le Calvez, SPIE OPTO, San Franisco, California, 2019.*
- *«InGaN/GaN µLED SPICE modelling with size-dependant ABC model integration», A. Daami, F. Olivier, SPIE OPTO, San Franisco, California, 2019.*

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Stéphanie Le Calvez
stephanie.le-calvez@cea.fr

Laurent Fulbert
laurent.fulbert@cea.fr

MEDICAL DEVICES & HEALTH

- ApneaBand
- Biocapan
- BitMAP
- D4Kids
- EUNCL
- Exucheck
- IDENTIFY
- INFORMED
- Innpaper
- LUMINT@CLINICS
- MEDTECH4 EUROPE
- NanoAthero
- Nareb
- NEW DEAL
- NOBEL
- ORCHID
- PANBioRA
- REFINE
- SOLUS
- VIRUSCAN

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ApneaBand

https://www.eithealth.eu/apneaband

Keywords
Healthcare efficiency
Optimized sleep diagnosis
Patient sleep empowerment
Simplified sleep technology
Sleep home monitoring
Wearable

ApneaBand at a glance

12 months
Jan. 2018 > Dec. 2018

EC Programme
eit health

Project Coordinator
CEA-Leti (FR)

Partners
ES: Agencia de Qualitat i Avaluacio Sanitaries de Catalunya, Universitat de Barcelona
FR: Airfan, Université Grenoble Alpes

Total budget
€ 0.5 m.

EC Contribution
€ 0.5 m.

Contract Number
18252

Sleep Apnea Diagnostic and Monitoring

Sleep disorder-related breathing is associated with many major chronic diseases (obesity, cancer, etc.) and remains widely underdiagnosed. ApneaBand is a non-intrusive medical screening method combining a wristband and AI software for home detection of Obstructive Sleep Apnea (OSA).

CEA-Leti in ApneaBand

ApneaBand has been validated under the CEA-Leti program of trials dedicated to home-based sleep apnea testing.

Thirty-seven patients spent no fewer than 74 nights with ApneaBand during clinical trials. These patients used the device under real life domestic conditions and their output data was processed by a clinical team using it for the first time.

ApneaBand has received positive feeback on usage from professionals and patients. Its impact on sleep quality is low, unlike the current reference system. A market study has shown that the ApneaBand concept is attractive for sleep apnea management in the countries, in which trials were conducted. Its cutting edge technical features include:

- Electronic design
- Supporting acquisition software
- An automatic detection algorithm
- A web-based interface dedicated to medical review of results.

Technical partner Airfan is committed to the solution's CE marking certification in conjunction with the CEA-Leti team.

Objectives

The ApneaBand project adapts and validates a wearable solution dedicated to respiratory sleep disorder event detection from device hardware to business plan. Validation of our solution (device + post processing software) has been based on clinical validation, usage validation and market validation. Adaptation of our solution to the market has been performed (for software and hardware following updated specifications) in relation to penetration strategy by a market study and to regulation rules by a market access study. Communications and solution testing have been conducted in relation to patients and professionals, stakeholders and the general population.

The project assesses how wider use of the wrist band for medical monitoring can improve medical data and facilitate healthier living. Ultimately, this work strengthens the strategy for bringing this product to market. The project has generated technical features required for real-life usage.



Sleep apnea diagnostic and monitoring.
© Airfan



ApneaBand. Exterior Design Airfan Electronic CEA-Leti.
© Airfan

IMPACT

ApneaBand is a disruptive technology for screening/diagnosing OSA in high risk patients not suffering from another form of sleep disorder-related breathing. ApneaBand TRL status has been upgraded and its performance characteristics have been initially evaluated during home trials. Partner Airfan has launched ApneaBand industrialisation and final CE marking.

TRL
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Laurent Gerfault
laurent.gerfault@cea.fr


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Biocapan

BIOCAPAN

www.biocapan.eu

Keywords
Bioactive microcapsule
Diabetes
Good Manufacturing Process (GMP)
Encapsulation platform
Microfluidics
Nanocharacterization

Biocapan at a glance

52 months
Jun. 2015 > Dec. 2019

EC Programme
H2020 NMP-10-2014 - Biomaterials for the treatment of diabetes mellitus

Project Coordinator
CEA-Leti (FR)

Partners
BE: Université catholique de Louvain (UCL)
DE: Charité-Universitätsmedizin Berlin (CUB), European Research Services GmbH (ERS)
ES: Nanoimmunotech (NIT)
FR: CEA-Leti, Etablissement Français du Sang (EFS), Universtié Grenoble Alpes (UGA)
NO: NovaMatrix/FMC BioPolymer (NOVA)
USA: Wake Forest University Health Sciences (WFUHS)

Total budget
€ 8 m.

EC Contribution
€ 8 m.

Contract Number
646272

BIOactive implantable CApsule for PANcreatic islet immunosuppression free therapy

463 million people suffer from diabetes, an incurable pandemic caused by the pancreas not producing enough insulin. The aim of the BIOCAPAN project was to develop innovative cell therapy based on grafting encapsulated human insulin secreting cells.

CEA-Leti in Biocapan

The strategy adopted for protecting pancreatic islets from immune rejection is to microencapsulate them in soft, porous, biocompatible microcapsules. CEA-Leti was project coordinator and leader for microcapsule production, characterisation, dissemination and planned usage.

New biomaterials were identified for inclusion in final bioactive capsule composition; these were optimised and tested in vitro and in vivo. This resulted in:
• Demonstration of the positive role of mesenchymal stem cells (MSCs) and tripeptides arginine-glycine-aspartic acid conjugated to sodium alginate (RGD-alginate) on rat islet viability and functionality through co-culture experiments
• Optimised production of GMP ultra pure Extra Cellular Matrix (ECM) mimicking the pancreatic islet microenvironment. Tests in vitro shown close biocompatibility and improvement in islet viability and functionality
• Development of a zwitterionic (ZW) chitosan for coating microcapsules and preventing fibrosis. ZW chitosan was shown to be biocompatible without affecting capsule porosity. Initial in vivo assays proved that ZW coating reduced macrophages in the capsule periphery.

These results enabled final bioactive capsule composition to be defined and patented.

The encapsulation challenge was to produce monodispersed microcapsules in the extremely high viscous fluid (10Pa.s) required by the microcapsule composition, while minimising the impact on cell viability. This was overcome by:
• Designing, manufacturing and testing an innovative, cheap, disposable, microfluidic plastic cartridge to produce the microcapsules automatically
• Designing and manufacturing new versatile GMP similar equipment. This automatically produces sterile capsules by simply plugging in the microfluidic cartridge and operating the patented instrument.

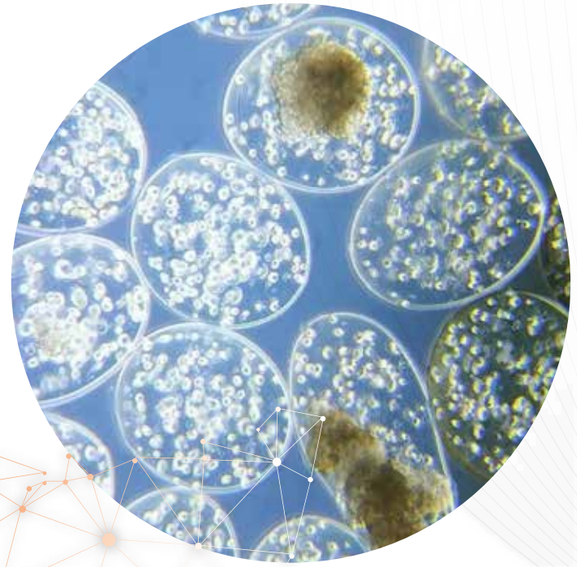
Capsules with allogenic islets were implanted into diabetic rats and shown good immunocompatibility and stability after several weeks.

Objectives

Glycaemic control is the key therapeutic issue in diabetes mellitus types I and II. Quality of life would benefit enormously from curtailment of constant self-control by insulin injection and long-term complications. The best therapeutic option is transplantation of allogeneic islet cells (from a human donor) but the current state of the art limits this approach's applicability. Implanting unprotected grafts demands lifelong administration of immunosuppressants. Moreover, cell protection against adverse immune reactions by today's encapsulation strategies so reduces graft functionality and survival that frequent 'refresher' implants are necessary. The encapsulated approach currently offers a maximum of two years glycaemia control.

The purpose of the BIOCAPAN project, which brought together experts from different fields, was to develop an innovative treatment based on implanting allogeneic islet cells embedded in a complex microcapsule. The objective was to design a GMP grade bioactive microcapsule that maximizes long-term functionality and survival of pancreatic islets by preventing pericapsular fibrotic overgrowth, in-situ oxygenation, innovative extracellular matrix microenvironment reconstruction and immune system modulation. CEA-Leti's mission was to establish a GMP grade microfluidic microencapsulation platform to protect freshly harvested islets quickly in a standardized, reproducible manner. The ambition was to design a microfluidic disposable cartridge the size of a credit card; this would be inserted into the equipment to produce microencapsulated islets automatically.

The project aimed for the full preclinical validation and a comprehensive protocol, complying with the provisions of Advanced Therapy Medicinal Products Regulation in order to start clinical trials within one year of project completion. The target was 5 years of insulin injection free treatment without immunosuppressants; this would be of enormous benefit to diabetes mellitus patients dependent on insulin (all Type I and approximately 1/6 Type II patients).



Human pancreatic islets encapsulated in the Biocapan microcapsule.
© CEA-Leti

IMPACT

Microencapsulation of islets in a viscous biopolymer is a world-class result. The project enabled definition and patenting of the microcapsule composition and the encapsulating instrument. The intention of the patenting strategy is to attract potential industrial partners for further commercialisation. The project built a strong relationship between its partners. Spin-offs in cell therapy product development are emerging from this collaboration and from the results of the BIOCAPAN project.

Publications

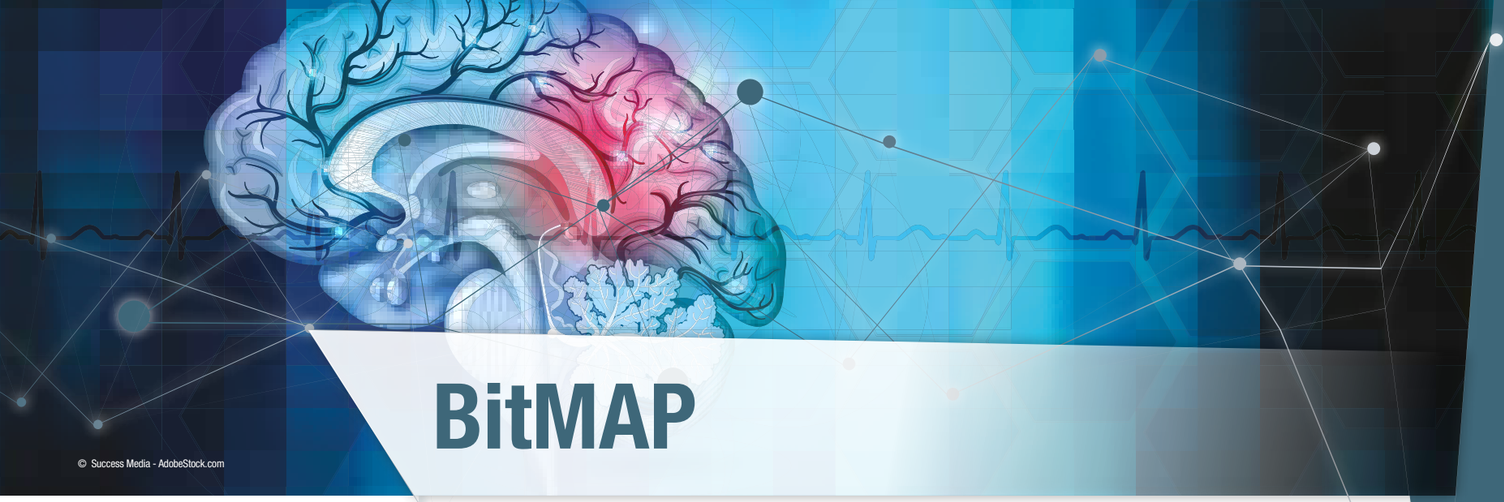
Oral presentations:
• «Innovative microfluidic-based technics for advance therapy medicinal product for the treatment of type-1 diabetes», F. Bottausci, M. Pierron, D. Rabaud, N. Sarrut, J.-L. Pesce, C.-E. Goujon, M. Alessio, F. Boizot, C. Fontelaye, E.Tubbs, C. Laporte, S .Lablanche, P.-Y.Benhamou, M. Orhant-Prioux, A. Moisan, F. Rivera, BioEngineering 2019 Summit - San Diego, USA - 1-2 April 2019.
• «Innovative microfluidic-based technics for advance therapy medicinal product for the treatment of type-1 diabetes», M. Pierron, F. Bottausci, D. Rabaud, N. Sarrut, J.-L. Pesce, C.-E. Goujon, M. Alessio, F. Boizot, C. Fontelaye, E. Tubbs, C. Laporte, S. Lablanche, P-Y.Benhamou, M. Orhant-Prioux, A. Moisan, F. Rivera, IEEE NEMS 2019 - Bangkok, Thailand - 11-14 April 2019.
• «BIOCAPAN: an innovative microcapsule-based advanced therapy medicinal product for the treatment of diabetes mellitus type I», F. Bottausci, M. Pierron, D. Rabaud, S. Lablanche, E.Tubbs, A. Moisan, K. Glinel, E. Giol, P. Gianello, M. Ramirez, G. Orlando, H. Bäumler, A. Gallego, T. Lozano, A. Hernández, L.-C.Asdahl, T. Svendsen, F. Rivera, TERMIS EU 2019, Rhodes, Greece, 27th to 31st of May 2019.

Article submitted in international journals:
«New microcapsule composite product for type 1 diabetes: bioprocessing and in vitro characterization», Acta-Biomaterialia – submitted, C. Laporte, E. Tubbs , M. Pierron, A. Gallego, A. Moisan, F. Lamarche, T. Lozano, A. Hernandez, C. Cottet-Rousselle, A.-S. Gauchez, V. Persoons, F. Bottausci, C. Fontelaye, F. Boizot, S. Lablanche and F. Rivera.

TRL
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Florence Rivera
florence.rivera@cea.fr

Frédéric Bottausci
frederic.bottausci@cea.fr



BitMAP

BitMap

http://www.bitmap-itn.eu/

Keywords
Diffuse optical tomography
Optics
Reconstruction

BitMAP at a glance

48 months
Jun. 2016 > Dec. 2019

EC Programme
H2020 MSCA-ITN-2015-ETN - Training Networks

Project Coordinator
University of Birmingham (GB)

Partners
DE: Physikalisch Technische Bundesanstalt, PicoQuant GmbH
FR: CEA-Leti
GB: University College London, University Hospital Birmingham
IT: Politecnico di Milano
PO: Institute of Biocybernetics and Biomedical Engineering
SP: Fundacio insitut de Ciencies Fotoniques (ICFO), HemoPhotonics, Vall D'Hebron University Hospital

Total budget
€ 3.8 m.

EC Contribution
€ 3.8 m.

Contract Number
675332

Brain Injury and Trauma Monitoring using Advanced Photonics

CEA-Leti is developing a method to diagnose head trauma using light. The amount of blood in the body can be measured using red light, so we are designing a device to installed in hospitals to measure head trauma severity.

CEA-Leti in BitMAP

CEA-Leti has been hosting a PhD student for 36 months under the auspices of Marie Curie ITN, an EC-funded laboratory group that is collaborating (15 doctoral theses) to develop a system for monitoring the blood parameters of Traumatism Brain Injury (TBI) in emergency services. This system is based on using near-infrared light to probe diffusing biological media in depth.

The CEA-Leti PhD student has been investigating new approaches to optical tomographic reconstruction by means of multispectral and time-resolved acquisition. Working in a highly reputed team dedicated to processing time-domain diffuse optical data, this has involved developing a time-domain multispectral optical tomography algorithm for monitoring blood parameters. More specifically, the Mellin-Laplace transform has been developed to process time-domain optical signal data in a computationally tractable manner.

The aim is to reconstruct in 3D the optical characteristics of monitored environments.
The approach involves:
• Focusing on late tenuous optical signals corresponding to light propagation deep within the medium
• Refining data analysis by incorporating a valid interference model
• Using priors such as sparsity for solving material-based decomposition problems. These algorithms are being initially tested and developed in simulations.
Project work in 2019 included taking part in acquisition campaign in POLIMI, implementing a supercontinuum laser source in conjunction with a wavelength selection system and resolved detection time. This campaign was used to validate real data developments.

CEA-Leti's outcomes:
• Scientific progress in time-domain diffuse optical data processing
• Progress in clinical translation of optical modality
• Strengthening relations between CEA-Leti and the project European laboratory through the presence and mobility of the Marie Curie ITN research student.

Objectives

Our vision is to develop a suite of standardized non-invasive devices that provides essential information about brain health in neurocritical care and neuromonitoring, with a particular emphasis on traumatic brain injury (the "silent epidemic of the third millennium") and hypoxia in newborn children. Survivors present permanent neurological conditions that have a profound impact on the quality of life of individuals and their families, and hence a large socio-economic impact. The key factors influencing these conditions and their treatment are the avoidance of brain hypoxia and metabolic disturbances and this is driving the transfer of new neuromonitoring systems to the bedside, where they are being shown to have a transformative effect on patient care.

BitMap develops non-invasive photonics-based monitoring techniques and data analysis methods to provide biomarkers that could guide patient management. A cohort of multi-disciplinary Early Stage Researchers (ESRs), embedded in leading laboratories across Europe, works together on an program designed to address the key technological and clinical challenges in neurocritical care. The ESRs benefit from the diverse range of expertise in advanced photonics and clinical application which substantially enhance their research competitiveness and employability, and together form a critical mass of skilled people working together towards new technologies for improved neuroclinical care.

The challenges involved are fundamentally multi-disciplinary and therefore ESRs trained in a multi-disciplinary environment are essential, if progress and clinical impact is to be made. There is currently no graduate program producing researchers with these attributes, but there is a significant market for such PhDs in the rapidly developing area of biomedical optics and in general in medical imaging technology development. The BitMap project therefore addresses both a clinical and economic need.



Fisrt meeting of BitMap highly talented Early Stage Researchers.
© BitMAP

IMPACT

BitMAP promotes the benefits of graduate and research partnerships, which have substantial impacts on European industry and the economy. These benefits include:
• Producing multi-skilled graduates capable of performing a transformative role by linking scientific domains and forming multidisciplinary teams for future employers
• The network and its graduates provides a direct route from industrial partners to academic science and IP base
• Using partnerships to circulate research results in industry.
CEA-Leti's project contribution has been development of data processing methods for time-domain measurements. Based on the reconstructions provided by CEA-Leti's new approach, the total measurement information could be exploited through the use of novel data filtering. Brain injuries can now be imaged deeper and more accurately: approximately 2.5cm under optical probes instead of 2cm for the same set of measurements.

Publications

Articles:
• *« Novel graph- and finite element-based total variation models for the inverse problem in diffuse optical tomography », W. Lu, J. Duan, D. Orive-Miguel, L. Hervé and I. Styles. Biomedical Optics Express. Paper.*
• *« Improving Localization of Deep Inclusions in Time-Resolved Diffuse Optical Tomography », Orive-Miguel, David & Hervé, Lionel & Condat, Laurent & Mars, Jerome. (2019).*

Communications:
• *« Time-resolved diffuse optical tomography: a novel method to compute datatypes allows better absorption quantification », D. Orive-Miguel, L. Hervé, J. Mars, L. Condat and P. Jallon, European conferences on biomedical optics, June 2019, Munich, Germany. Talk and proceedings.*
• *« The BitMap dataset: an open dataset on performance assessment of diffuse optics instruments », D. Orive-Miguel et al. European conferences on biomedical optics, June 2019, Munich, Germany. Talk and proceedings.*
• *« Computational performance of time-resolved diffuse optical tomography in a two-layer brain model », D. Orive-Miguel, L. Herve, J. Mars, L. Condat, J.-M. Dinten, and S. Morales, Biophotonics congress: biomedical optics congress 2018, April 2018, Miami, USA. Poster.*
• *« A performance comparison between continuous-wave and time-domain diffuse optical tomography for deep inclusions by using small source-detector separations », D. Orive-Miguel, J.-M. Dinten, J. Mars, L. Condat, L. Hervé, 12e Journées imagerie optique non-conventionnelle (JIONC 2017), Mars 2017, Paris, France. Talk and proceedings.*
• *« Performance evaluation of time-domain multispectral diffuse optical tomography in the reflection geometry », J. Zouaoui, D. Orive-Miguel, L. Di Sieno, L. Herve, A. Pieri, A. Farina, A. Dalla Mora, J. Derouard, J. Mars, L. Condat and J.-M. Dinten, European conferences on biomedical optics, June 2017, Munich, Germany. Talk and proceedings.*

TRL
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Lionel Hervé
lionel.herve@cea.fr


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D4Kids

Objectives

Diabetes in children (6 to 10 years old) is characterized by high insulin sensitivity and high blood glucose variability due to unpredictable physical activity and higher glycemic response to carbohydrate intake. Diabeloop's artificial pancreas adaptation to children started with a pilot study to collect glucose and insulin data of a few children treated with an insulin pump over a period of 4 weeks. Based on this data, our EIT Health project focused on adapting the closed loop system along two axes: fine-tuning of entry parameters and adaptation of both the closed-loop algorithm and the HMI (Human Machine Interface). The D4KIDS solution is to be validated clinically in a randomized cross-over design with 6 children during 2 days in KU Leuven under CERITD promotion. A complementary study (KCA) will be conducted on 24 diabetic children in 2 hospitals in France. Ergonomy and user-friendliness of the interface were assessed and CERITD elaborated the educational kit for children, parents, and caregivers, and test in KU Leuven. Diabeloop defined with Profil a penetration access strategy for the new product in European countries.

https://www.eithealth.eu/en_US/diabeloop-for-children

Keywords
Artificial pancreas
Children
Closed-loop metabolic control
Co-creation
Digital health
Medical device
Model-predictive-control
Type 1 diabetes

D4Kids at a glance

12 months
Jan. 2018 > Dec. 2018

EC Programme
EITHealth 18178
Diabeloop for Children

Project Coordinator
CEA-Leti (FR)

Partners
BE: Katholieke Universiteit Leuven
DE: Profil Institut für Stoffwechselforschung GmbH
FR: CERITD, Diabeloop SA

Total budget
€ 9.1 m.

EC Contribution
€ 0.5 sur 12 mois

Contract Number
X30464

EITHealth 18178 Diabeloop for Children

Children living with Type 1 diabetes have to sustain the burden of frequently checking their glycaemia (for meals and physical activity). The D4Kids project has developed a medical device for regulating insulin delivery in real time that is tailored to these children's needs. The system allows remote monitoring by parents.

CEA-Leti in D4Kids

CEA-Leti has mainly contributed to the technological aspect of the project and, more specifically, to data analysis, algorithm development and establishment of a bio-regulation computing library in compliance with regulatory rules governing medical devices. The project team initially received data from clinicians, who provided information on the children's normal treatment. This included glucose measurements from Continuous Glucose Measurement (CGM) sensors, insulin delivery with either bolus and basal doses, meal time and size. This allowed us to compare, for example the glycemic trends of children and various populations already on CEA-Leti databases (adults using open-loop and closed-loop systems). This European project has been undertaken in parallel with the work of a laboratory developing an artificial pancreas for adults, which combines CEA-Leti and partners Diabeloop SA (medical device manufacturer) and CERITD (diabetologists and clinical research organization). The medical device for adults was CE-marked in autumn 2018 and the children's device could take advantage of previous developments for adults. Most of the bioregulation algorithm is based on the Hovorka model (Hovorka et al. 2002, 2004); its personalization step is of prime importance. We used a Model Predictive Control approach because the model's capacity to understand the patient physiology at any instant was crucial to determining the right insulin dose to be delivered at the right time. On completion of the project in 2019, the prototype was used in clinical trials in France and Belgium. Some 25 children were equipped with the child's artificial pancreas during 6 weeks of everyday life. Child patients, their parents and pediatric diabetologists are very enthusiastic about the results. In May 2019, EITHealth selected Diabeloop SA as a D4Kids project partner to represent EITHealth at the EIT Innovator Awards.



Schematic view of the artificial pancreas user interface adapted for use by children. The screenshots are prototype frames, with rights reserved.
© Diabeloop

Publications

«Comparing the glucose kinetics of children and adults to adapt predictive low-glucose suspend», E. Villeneuve, R. Blanc, K. Casteels, H. Morobé, E. Van Doorne, E. Huneker, G. Charpentier, M. Doron on behalf of the Diabeloop study group, Diabetes Technology Meeting, Bethesda (USA), 8-10/11/2018.

IMPACT

A first impact is removal of a considerable burden from the daily lives of both children and their families: fewer mild hypoglycemic events (several a week) and severe hypoglycemia at night. A second impact is reduction of long-term complications, thereby greatly reducing the costs of T1DM throughout the patient's life. The artificial pancreas for children (6-12 years) DBLK will undoubtedly be a worldwide innovation. In 2019, EITHealth provided funding for a new project dedicated developing an artificial pancreas for teenagers.

TRL
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Maeva Doron
maeva.doron@cea.fr



EUNCL

Objectives

• To provide a trans-disciplinary testing infrastructure covering a comprehensive set of preclinical characterisation assays (physical, chemical, in-vitro and in-vivo biological testing) allowing researchers to fully comprehend the biodistribution, metabolism, pharmacokinetics, safety profiles and immunological effects of nanoparticles used for medical applications (Med-NPs).

• To foster the use and deployment of standard operating procedures (SOPs), benchmark materials and quality management for the preclinical characterization of Med-NPs.

• To promote inter-sectorial and inter-disciplinary communication among key drivers of innovation, especially between developers and regulatory agencies.

EUropean Nanomedicine Characterization Laboratory

EUNCL is the European reference Nanomedicine Characterization Laboratory performing full physical, chemical and biological characterization of nanomedicinal products before regulatory application. The full characterization assay cascade has been permanently updated with regulators in response to needs. Thirty-plus nanomedicinal products were accepted by EUNCL between 2016 and 2019.

http://euncl.eu

Keywords
Characterization
Infrastructure
Medicinal products
Nanomedicine
Preclinical
RegulationSurgery

EUNCL at a glance

54 months
May 2015 > Nov. 2019

EC Programme
H2020 INFRAIA-1-2014-2015 - Integrating and opening existing national and regional research infrastructures of European interest

Project Coordinator
CEA-Leti (FR)

Partners
CH: EMPA
DE: European Research Services, NanoBioAnalytik Münster
IE: Trinity College
IT: JRC-Ispra
NO: SINTEF Trondheim
UK: University of Liverpool
US: SAIC - Frederick

Total budget
€ 5.6 m.

EC Contribution
€ 5.6 m.

Contract Number
654190

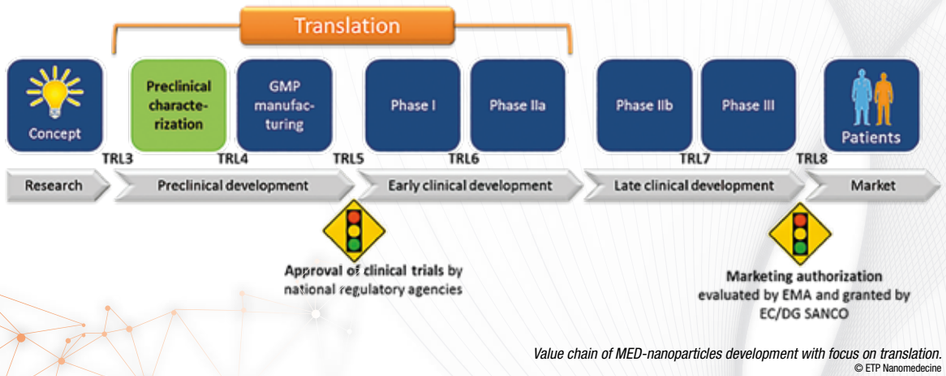
CEA-Leti in EUNCL

CEA-Leti's contribution

• General coordination of infrastructure
• Coordination of trans-national access
• Responsibility for physical and chemical characterization.

Outcomes

• Efficient synchronization and alignment with CEA-Liten Nano Safety Platform (PNS)
• Physical and chemical characterization of 5 nanomedicinal products
• EU leadership in characterization of nanomedicinal products
• Coordination of REFINE spin-off project on regulatory science framework of nanomedicinal products and nanobiomaterial-enabled medical devices.
• Strong attractiveness of Grenoble as a place for developing nanomedicinal products (formulation, characterization, scale-up manufacturing).



Value chain of MED-nanoparticles development with focus on translation.
© ETP Nanomedecine

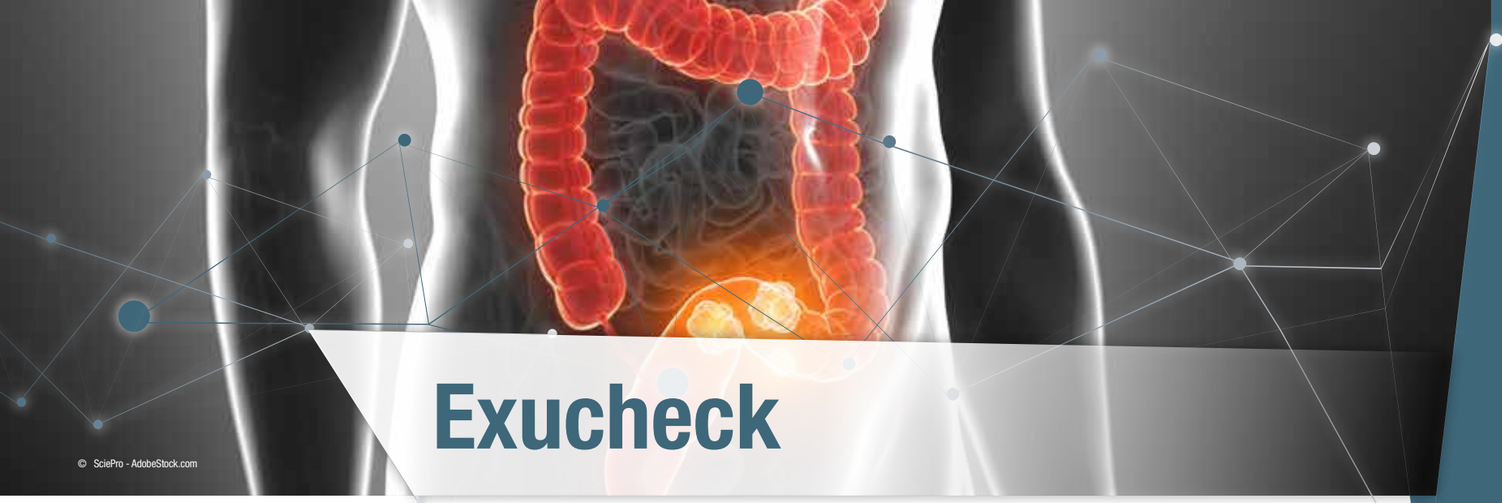


IMPACT

EUNCL is now performing as well as its US counterpart NCI-NCL in terms of quality and excellence. The European Community refers to EU-US cooperation in nanomedicinal product characterization as «the most successful cooperation in the field of nanotechnologies». The European Medicine Agency is now recognising EUNCL as the reference research infrastructure in Europe.

TRL
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Simon Baconnier
simon.baconnier@cea.fr



Exucheck

Objectives

Exucheck aims at providing a technological breakthrough in the early detection of one of the most common complications, post-operative infection, by detecting infection resulting from anastomosis leakage following colorectal surgery.

A new and innovative diagnosis approach has been developed based on a smart sensor system integrated within a drain to monitor in real-time relevant parameters related to infection. The identification of the presence of specific bacteria is not adapted for the targeted clinical application as too many different species are involved. The sensing device therefore focuses on two indirect biomarkers identified by previous studies led by ERASMUS and MEDTRONIC: pH and lactic acid concentration.

A first Proof of Concept with a drain integrated with a pH sensor has been developed jointly by CEA and MEDTRONIC.

The overall goal of the project is to bring the ExuCheck solution to an acceptable level of risk for further investments by MEDTRONIC, ensuring internal funding for the launch of large-scale clinical studies and industrialization.

Efforts are focused on developing the system until clinical trials are launched, assessing its ease of use and medico-economic impact.

Keywords
Biomarkers
Colorectal cancer
Drain
Gastroenterology
Gastrointestinal system diseases
Infection detection
Lactate
Medical device
pH
Sensors
Surgery

Exucheck at a glance

18 months
Jan. 2019 > Jun. 2020

EC Programme
EIT Health

PRoject Coordinator
Medtronic (UK)

Partners
FR: Bürkert, CEA-Leti, Maatel, Université Grenoble Alpes
NL: Erasmus Universiteit Medisch Centrum Rotterdam

Total budget
€ 0.7 m.

EC Contribution
€ 0.7 m.

Contract Number
19296

Smart Drain for Early Detection of Post-Operative Infection

The ExuCheck project targets a breakthrough in early detection of one of the most common clinical complications, namely post-operative infection, based around an analytical device (measuring pH & lactate) and an algorithm for interpreting variations in the possible patient infection markers.

CEA-Leti in Exucheck

CEA-Leti had formerly developed micro-electrochemical sensors for measuring pH and lactic acid.

CEA-Leti's principal aims within the Exucheck project

• The lactic acid sensor developed by CEA-Leti performed acceptably, however it had only been assessed in laboratory conditions and in model solutions (e.g. PBS). CEA-Leti's principal project aim involves ensuring full lactic acid sensor compatibility with the application by:
> Ensuring sensor compatibility with sterilization (e.g. gamma radiation)
> Assessing sensor robustness to interferent species present in the exudates
> Assessing sensor biocompatibility
> Ensuring at least 5 days functional stability, i.e. developing dedicated anti-biofouling layers
> Testing the sensor in real exudates.

• CEA-Leti anticipates developing the complete system. The main task involves integrating the existing pH and lactic acid sensors into a unique platform with suitable electrical and fluid connections prior to full platform characterization. This work will be performed in close collaboration with Maatel, which is developing the electronic and HMI parts.

• CEA-Leti will be involved in preclinical testing on completion of the project. Here, our main role will be fabrication of dedicated sensor platforms.

• CEA-Leti is contributing to the sensor industrialization plan along with the project industrial partners.



ExuCheck analytical device (prototype) : cartridge with pH and lactate sensors, integrated into the drain line, classically used after a colorectal surgery.
© CEA-Leti

IMPACT

In the short term: advancement of scientific knowledge through sharing research results with the scientific community.
In the medium term: reducing project risks and preparing deployment (supply chain, business plan) to create a new MEDTRONIC range.
In the long term: if the smart drain meets the clinical and commercial expectations, new generations of MEDTRONIC sensing systems may be considered, e.g. smart implants.

TRL
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Véronique Mourier
veronique.mourier@cea.fr



IDENTIFY

Improved Diagnosis By Fast Field-Cycling MRI

The goal of the IDentIFY project is to develop a new generation of Magnetic Resonance Imaging (MRI) scanners capable of detecting certain diseases that are invisible to conventional scanners. An MRI can study large objects (e.g. a head) and produces images of them, whereas an NMR can only analyze small samples and cannot image them.
Multiple challenges must be overcome before such devices can be deployed in hospitals, among them controlling the magnetic field in the vicinity of the equipment.

https://webhost.abdn.ac.uk/dev-identify/

Keywords
Contrast agents
Field-cycling
Magnetic Resonance Imaging (MRI)
Medical imaging
Relaxometry

IDENTIFY at a glance

48 months
Jan.2016 > Dec. 2019

EC Programme
PHC-11-2015 Development of new diagnostic tools and technologies: in vivo medical imaging technologies

Project Coordinator
University of Aberdeen (GB)

Partners
DE: Tuil
FI: Ieco
FR: CEA-Leti, Cnrs, Inserm
GB: Iniabdn
IT: Unito, Stelar
PL: Uwm

Total budget
€ 6.6 m.

EC Contribution
€ 6.6 m.

Contract Number
668119

CEA-Leti in IDENTIFY

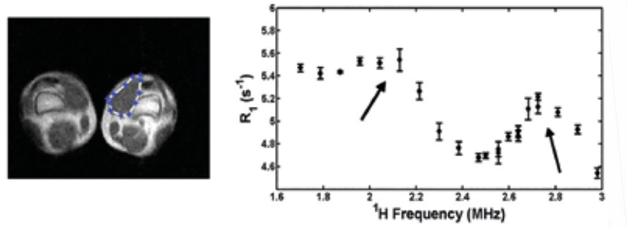
FFC-MRI requires measurement and elimination of interfering magnetic fields in the vicinity of the MRI system. This requires development of new active magnetic shielding.
The aim of the CEA-Leti and CNRS research is to compensate for static and time varying (<500 Hz) magnetic fields in the vicinity of Grenoble-based NMR and Aberdeen-based MRI systems and to generate relaxation fields for ultralow FFC-NMR/MRI measurements in the 2µT - 1mT range.

This work has been broken down the following key steps:
• Roll out magnetic sensors for measuring magnetic environments
• Develop mathematical models for magnetic interference sources (static and time-varying)
• Based on these models, design coils to compensate for DC & AC interference fields, when using ultra- and very-low fields (from 2µT to 1mT, free of interference <500 Hz)
• Develop and implement the coils in Grenoble (on the NMR system) and Aberdeen (on the MRI system)
• Implement automatic compensation software for the FFC-NMR and FFC-MRI systems.

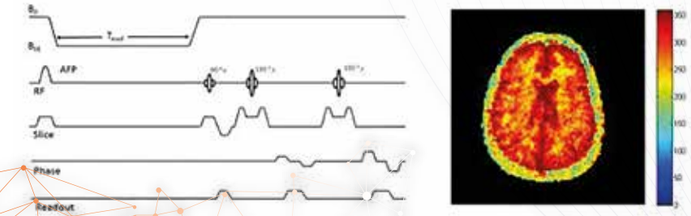
This project has allowed CEA-Leti to:
• Reinforce relations between the CEA-Leti partners (INAC / Clinatec) and Grenoble partners (G2ELAB at Grenoble INP, CNRS) and build new partnerships with scientific institutions in Germany, Poland and Italy
• Develop two very-low noise power supplies for the NMR and MRI systems
• Develop cutting edge technology for magnetic shielding, which will be reusable for others projects requiring elimination of magnetic interference
• Develop its expertise in the field of medical imaging
• Prepare the new generation of portable, ultra-low field NMR systems allowing on-site analysis.

Objectives

Many diseases are inadequately diagnosed or not diagnosed early enough by current imaging methods. Fast Field-Cycling (FFC) MRI can measure quantitative information that is invisible to standard MRI. FFC scanners switch magnetic field while scanning the patient to obtain new diagnostic information.
The main IDentIFY project aims are:
• To understand the mechanisms determining FFC signals in human tissues
• To create technology to measure and correct for environmental magnetic fields, enabling FFC at ultra-low fields
• To investigate contrast agents for FFC to increase sensitivity and to allow molecular imaging
• To improve FFC technology to extend its range of clinical applications
• To test FFC-MRI on tissue samples and patients.
These aims are being achieved by:
• Developing tissue relaxation theory for ultra-low fields
• Developing magnetometers and environmental field correction
• Creating and in-vitro testing new FFC contrast agents
• Improving technology to monitor and stabilize magnetic fields in FFC
• Improving magnet power supply stability
• Investigating better radiofrequency coils and acquisition pulse sequences.



Left: navigator image (59 mT) of the thighs of a healthy volunteer, obtained using an FFC-MRI scanner. Right: FFC dispersion curve obtained on the same volunteer from the muscle region-of-interest shown on the image. Quadrupole peaks are indicated by arrows.
© University of Aberdeen



FFC-MRI pulse sequence and a T1 image obtained at a field strengh of 49mT. Our objective os to go as low as 2mT.
© University of Aberdeen

IMPACT

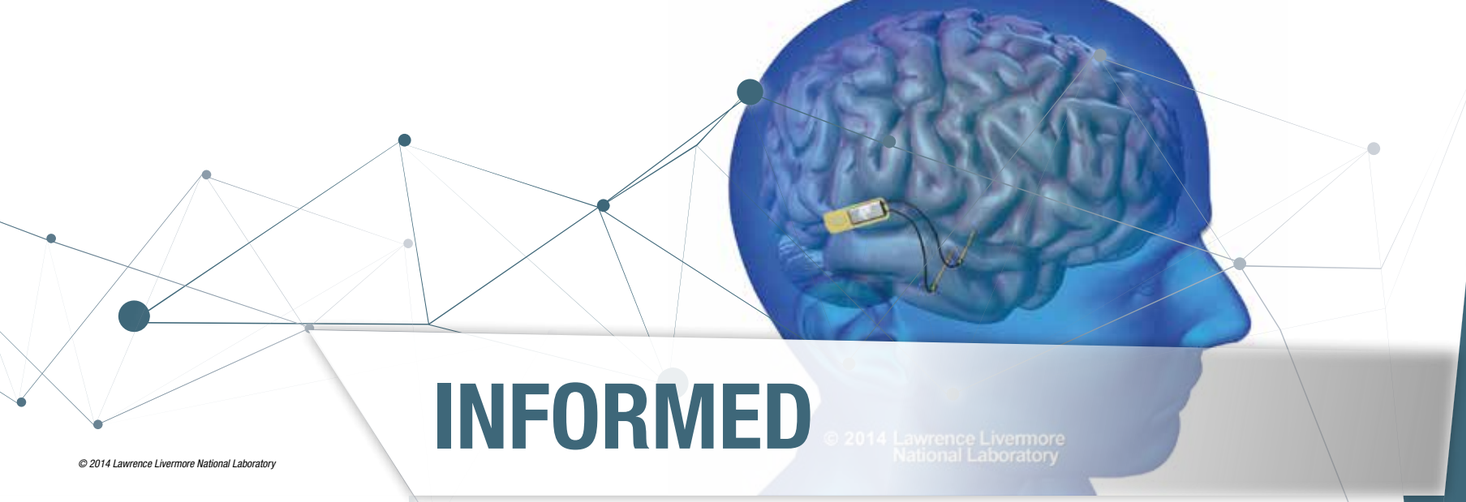
Development of a new generation of MRI scanner requires a broad range of high-level technological, biological and medical expertise. Allocation of cooperative research resources to a pool of experts for developing a new MRI makes Europe the frontrunner in diagnosing several pathologies that are currently invisible to conventional MRI scanners. It also offers Europe a technological and commercial lead in the area of medical imaging devices their commercialization.

Publications
«Optimization-based ambient field compensation applied to fast-field cycling nuclear magnetic resonance experiments», L.B. Martinho, O. Chadebec, O. Pinaud, L. L. Rouve, J. L. Coulomb, A. Viana, ... & Ferrante, G. (2017, November), in NUMELEC 2017-9e Conférence Européenne sur les Méthodes Numériques en Electromagnétisme.

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Antoine Viana
antoine.viana@cea.fr

Bernard Strée
bernard.stree@cea.fr



INFORMED

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informed-project.eu

Keywords
Biocompatibility
Medical devices
Miniaturization
Packaging
Pilot line

INFORMED at a glance

39 months
Jun. 2015 > Sep. 2018

EC Programme
Ecsel-2014-2 Innovation Actions (IA)

Project Coordinator
Philips (NL)

Partners
BE: ICScience, Imec, Rsscan
CH: Comelec
DE: Brio Alphasip, Cytocentrics Bioscience, Fraunhofer, JVI, Lust Hybrid, Multi Channel, Osypka, SPTS
FI: Aalto, Okmetic, Picosun, VTT
FR: CEA-Leti, ESIEE, Ipdia, Packaging SIP, SAS Bodycap, Smith Connectors, Toppan
IE: Fleming Medical, Tyndall
NL: BESI, Boschman Technology, Cytocentrics BV, IMDS Service, Iszgro Diodes BV, Medtronic, Micronit, Philips, Philips Healthcare, Pluriomics, TNO Holst Center, TU Delft
SE: Silex
SP: Univ Zaragoza

Total budget
€ 48.1 m.

EC Contribution
€ 11.4 m.

Contract Number
ECSEL2014-2-662155

An integrated pilot line for micro-fabricated medical devices

The InForMed project is ensuring development of a new generation of medical instruments, including laparoscopic instruments, catheters and guide-wires, which will be used in Hospital and Heuristic Care, Home Care and Well-being.

Objectives

The goal of the InForMed project is to set up an integrated micro-fabrication pilot line for medical devices, covering the complete innovation chain from technology concept to system qualification. The critical stages of technology transfer from university to industrial development (TRL 4/5) and subsequent qualification for manufacturing (TRL7/8) are specifically addressed. A number of innovative micro-fabricated medical devices serve as pilot products to identify and resolve all possible transfer issues along the value chain. This allows validation of the complete integrated pilot line infrastructure from novel idea to real product. The InForMed project targets innovation in three important classes of medical equipment and instruments:

• Traditional diagnostic equipment: micro-fabricated devices are rapidly replacing traditional sensors and actuators in diagnostic equipment

• Next generation medical instruments: more and more medical procedures are performed using minimally invasive techniques involving laparoscopic instruments, catheters or guide-wires

• Organs-on-Chip and other emerging devices, micro-fluidics and polymer micro-fabrication combined with breakthroughs in cell-biology, in particular recently developed induced Pluripotent Stem Cell technology (iPSC), which leads to co-integration of living cells and tissue with micro-fabricated devices to form accurate models of human organs.
CEA-Leti has contributed to the InForMed project through its expertise in 3D packaging of microsystems and deposition of material for stimulation electrodes.

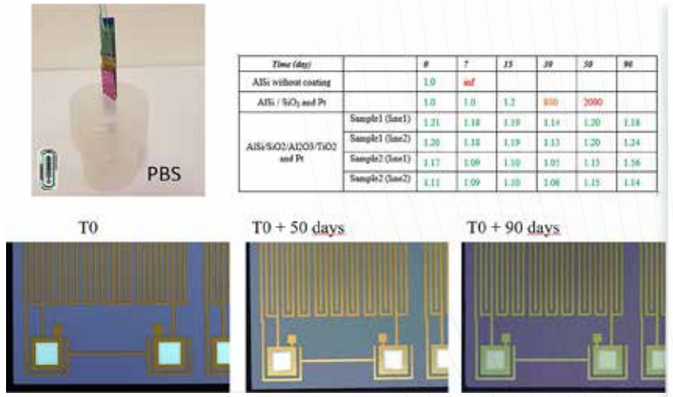
CEA-Leti in INFORMED

CEA-Leti has contributed to the InForMed project through its expertise in 3D packaging of microsystems and deposition of material for stimulation electrodes.

Study of thin layer biocompatible encapsulation has highlighted the following candidates: TiO_2, HfO_2, Al_2O_3-TiO_2, Pt and Ti-TiN deposited by ALD. Most of these thin layers are very stable in PBS at 90°C. It has also been shown that the ALD layer comprising Al_2O_3-TiO_2 on SiO_2 offers a good barrier to PBS infiltration. No degradation of AlSi lines were observed after 90 days in PBS at 90°C. Finally, it has also been demonstrated that 500nn of Pt was a good candidate for encapsulating AlSi.

The PEDOT electropolymerization method has been confirmed in the Steering deep brain stimulation demonstrator: the CV method ensures the best PEDOT film properties (Charge Storage Capacities (CSC) and impedances). Moreover, a method has been optimized for grafting a molecule to improve the PEDOT electrodeposition and adhesion to the platinum surface. Electropolymerization has been performed on Medtronic test vehicles with different electrode shapes and sizes on a flexible Parylene substrate. Electrodeposition has given excellent results.

Time (days)		0	7	15	30	50	90
AlSi without coating		1.0	ouf				
AlSi / SiO_2 and Pt		1.0	1.0	1.2	800	2000	
AlSi/SiO2/Al2O3/TiO2 and Pt	Sample1 (line1)	1.21	1.18	1.19	1.14	1.20	1.18
	Sample1 (line2)	1.20	1.18	1.19	1.13	1.20	1.24
	Sample2 (line1)	1.17	1.09	1.10	1.01	1.13	1.56
	Sample2 (line2)	1.11	1.09	1.10	1.08	1.13	1.14



Observation and resistance of electrical line (in kΩ) versus time during immersion in PBS at 90°C.
© CEA-Leti



Test vehicle developed by CEA-Leti for the optimization of PEDOT electrodeposition parameters.
© CEA-Leti

IMPACT

Material bio-compatibility and bio-stability in medical devices is a real challenge, especially when materials are deposited in thin layers.

CEA-Leti's work on the InForMed project has been decisive for developing implantable devices and neurological stimulation. The results obtained are very positive and are universally recognized by the scientific community.

Publications

• *«Development of micro-system encapsulation for silicon devices which are in contact with human cells», J.-C. Souriau et al; IEEE CPMT Symposium Japan (ICSJ) 2017.*
• *«Evaluation of thin biocompatible barriers properties on A none-Biocompatible silicon test vehicle», J.-C. Souriau, C. Quiniou, L. Castagné, G. Simon; 4th ATW on Microelectronics, Systems and Packaging for Medical Applications December 7-8, 2016 Lyon, France.*
• *«PEDOT and Iridium Oxide (SIROF) Ageing for Neural Stimulation», G. Grenot et al; 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'16), 2016.*

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Jean-Charles Souriau
jean-charles.souriau@cea.fr


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INNPAPER

Objectives

Flexible, easily foldable and recyclable paper, used as a substrate and functional part of portable, wireless and/or disposable electronic devices, is emerging as a promising material for developing sustainable electronic components that generate less waste. INNPAPER is a use case-driven project that provides a configurable common electronic platform based on multifunctional paper. The project is developing innovative approaches to paper manufacturing, including (Nano) cellulose functionalization, to produce paper with custom properties ((super)hydrophobicity/philicity, conductivity, etc.) at surface and body levels. A configurable common platform featuring a variety of paper-based devices (printed battery, electrochromic display, antenna and hybrid electronic circuit) is being developed on which paper will act as substrate and active component. This common platform underpins manufacturing of several use cases in different industrial sectors, especially packaging and Point of Care (PoC) assays (security, food traceability, and medical). The paper-based platforms are fabricated on existing pilot printing and hybrid production lines at the project partners' facilities. This is creating a business case involving not only a high impact paper-based electronics, but also an open-access pilot line network for the EU. An eco-design strategy, including sustainability and re-use considerations, is being implemented. An operation and business plan is being drawn up to ensure the short- and long-term profitability of the pilot lines as well as commercialization of resulting paper-based platforms. Achieving INNPAPER targets supports EU industry in the emerging Internet of Things and consolidates paper making and wood harvesting industries as well as the EU's position environmental management of electronic waste.

INNPAPER
http://innpaper.eu/

Keywords
Bioplatform
(Bio)sensors
Flexible
Hybridization
(Nano)cellulose
Paper-based electronics
Point-of-care devices
Printed electronics
Printed
smart labelling
TOLAE

INNPAPER at a glance

42 months
Jan. 2018 > Jun. 2021

EC Programme
H2020-NMBP-PILOTS-2017

Project Coordinator
CIDETEC-IK4 Research Alliance (ES)

Partners
BE: Coris BioConcept
DE: Securetec Detektions-Systeme, Varta
ES: Biolan Microbiosensores, Cidetec-IK4, Guarro Casas, Scienseed
FI: Aalto University, Spinverse, VTT
FR: AMU (Université d'Aix Marseille), CEA (Leti, Liten), Vertech-Group
NO: Skanem
PT: YD Ynvisible

Total budget
€ 7.4 m.

EC Contribution
€ 7.4 m.

Contract Number
760876

Innovative and Smart Printed Electronics based on Multifunctionalized Paper: from Smart Labelling to Point of Care Bioplatforms

The INNPAPER project is aimed at creating configurable, recyclable common platform that integrates a variety of paper-based electronic devices into a multifunctional paper sheet to allow subsequent production of multiple use cases. The ultimate aim of the project is to demonstrate the feasibility of the paper-based common electronic platform, on which paper is used as both the substrate and the active component, by developing real use cases (smart labels and PoC bioplatforms). The paper-based common electronic platform and its resulting use case demonstrators will be manufactured on a multi-site pilot line at the INNPAPER consortium's multidisciplinary partner facilities.

CEA-Leti in INNPAPER

Design and development of a paper-based electrochemical genosensors that integrate sample preparation, DNA amplification and DNA detection into one system to be used in streptococcus bacteria and influenza virus detection in saliva, nasal specimens and throat swabs.

• Fabrication of a microfluidic, electrochemical, paper-based Analytical Device (µePAD):
> Designing a microfluidic paper technology compatible with LAMP amplification
> Printing of reference and operating DNA electrodes at top of custom paper-based chamber
> Optimizing the printing process (inks, mesh characteristics and printing parameters) for the plastic, electrochemical genosensor to produce a well-defined, reproducible µePAD for DNA amplification and detection using INNPAPER paper.

• Modification of µePADs using bioreagents:
> Developing specific reagents and bioreagents for sample pretreatment, DNA amplification and DNA detection. Establishing sample pretreatment protocols and modifying the microfluidic channel in one zone (sample pretreatment) using reagents for sample dilution and DNA extraction
> Modifying the paper-based LAMP chamber using bioreagents (primers) for DNA amplification
> Optimizing all parameters involving sample pretreatment, LAMP, amplification and DNA detection (type/quantity of bioreagents).

• Application of new paper-based electrochemical genosensors to streptococcus bacteria and influenza virus detection:
> Comparing results with those obtained using official method (e.g. quantitative PCR)
> Integrating paper-based electrochemical genosensors into common platform to produce the final integrated PoC genetic assay.



Use case INNPAPER.
© Innpaper

IMPACT

• A new disruptive, sustainable, paper-based electronics platform, which not only integrates discrete devices, but also uses cellulose as an electronic material for insulators, electrolytes, conductors and semiconductors.

• Use of same paper substrate used to support electronics to drive ECDs, communication systems, PoC bioplatforms and smart labels, based on an embedded chemical battery power source.

• Reduction of the environmental impact of electronics.

Publications

• *«All-in-One Gel-Based Electrochromic Devices: Strengths and Recent Developments», Y. Alesanco, A. Viñuales, J. Rodriguez & R. Tena-Zaera, (2018). Materials, 11(3), 414.*
• *«Two-Dimensional Antifouling Fluidic Channels on Nanopapers for Biosensing», K. Solin, H. Orelma, M. Borghei, M. Vuoriluoto, R. Koivunen, and O. J. Rojas, Biomacromolecules, DOI: 10.1021/acs.biomac.8b01656.*

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Raphaël Trouillon
raphael.trouillon@cea.fr



LUMINT@CLINICS

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https://www.eithealth.eu/innovation_projects

Keywords
Artifical intelligence
Bacteria identification
Diagnosis
Elastic light scattering
Optics

LUMINT at a glance

18 months
Jan. 2019 > Jun. 2020

EC Programme
EIT-Health

Project Coordinator
CEA-Leti (FR)

Partners
BE: Laboratorium voor Medische Microbiologie, Medisch diensthoofd, Universieit Gent
FR: Assistance Publique Hôpitaux de Paris, Hôpital Européen Georges Pompidou, Service de microbiologie

Total budget
€ 0.7 m.

EC Contribution
€ 0.7 m.

Contract Number
19132-Lumint@Clinics

Elastic Light Scattering for low cost and non-destructive clinical pathogens identification

LUMINT technology is an innovative diagnostic tool that implements imaging technology and artificial intelligence. The project aim is to identify automatically bacterial pathogens and help clinicians in their therapeutic decisions. The LUMINT@CLINICS project aims to transfer this technology from the laboratory to the hospital.

CEA-Leti in LUMINT

The LUMINT@CLINICS project is a unique opportunity for transferring LUMINT technology to the application field by:

- Building 2 fully integrated prototypes, designed to be user-friendly, based on a laboratory system previously developed by CEA-Leti and successfully assessed under laboratory conditions for 10 standard bacterial species
- Installing prototypes in two microbiological laboratories at Georges Pompidou European Hospital (HEGP) and Ghent University Hospital (UZGENT) and training clinicians to operate the instruments themselves
- Assessing these prototypes in real conditions, i.e. during routine clinical practice, to build up a clinical sample database for the 40 most common bacterial species representing over 90% of pathogens in hospitals. Large-scale data collection is the first step towards truly demonstrating feasibility and, although it represents a key achievement, it has not yet been reported in the literature
- Ensuring availability of 2 harmonized data sets acquired in 2 different laboratories, which will help in drawing up a coherent LUMINT development plan
- Assessing identification performance with respect to today's standard mass spectrometry analysis.

CEA-Leti's outcomes include a general upgrade of the LUMINT chain from instrument to AI algorithms and availability of a clinical database double-validated using a gold standard test. A 1 point increase in TRL index (from 4 to 5) is expected during the project. In addition to technological achievements, CEA-Leti is benefitting from fruitful collaboration with clinician partners, who can share their knowledge of real practice constraints as well as present and future needs.

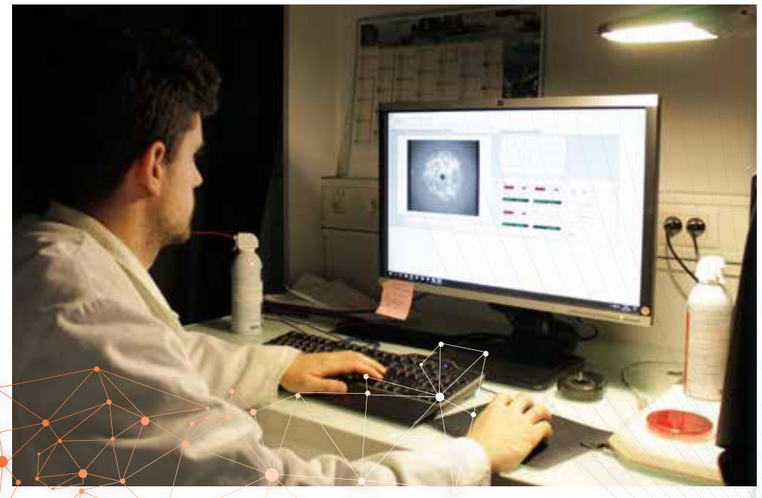
Objectives

LUMINT is an innovative pathogen identification tool based on a light scattering technique and artificial intelligence. Elastic light scattering technology relies on the fact that a cell illuminated by a laser beam scatters light in a specific pattern. Using the recorded patterns, AI makes it possible to rapidly identify bacteria. A first proof of concept has already been successfully achieved based on acquisition and laboratory analysis of 10 frequent bacteria species.

The LUMINT@CLINICS project aims to translate the tool to a clinical level. It is mandatory to assess its performance on clinical isolates and compare them to the gold standard technique (mass-spectrometry or genetic methods). The study involves two hospitals - Assistance Publique-Hopitaux De Paris (APHP) and Ghent University (UZGENT) - where image database can be acquired on the 40 most common pathogens in clinical practice, representing 90% of the samples collected in hospitals. Automatic identification using optimized algorithms will then be performed.

An organizational impact study as well as a detailed business plan setup are also included in the project.

The outcome of Lumint@Clinics is decisive to raise the necessary funding for the next development steps: large data acquisition campaigns and in vitro diagnostic regulatory trials.



Pathogens identification results.
© CEA-Leti

IMPACT

Bacteria and viruses resistant to antimicrobials are a growing problem in today's world. Time is of the essence in identifying rapidly multiplying bacteria. Bacteria identification is crucial to optimal therapy and speedy, reliable diagnostics are at the heart of the fight against resistant superbugs.

The LUMINT solution can potentially have a huge impact on microbiology laboratory organization. This project may revolutionize processes at microbiological laboratories because it will perform faster, non-destructive, fully automated analysis, potentially facilitating chain identification and antibiotic susceptibility testing. The development of this new pathogen identification system is therefore at the heart of the fight against resistant superbugs.

Publications

- *« Elastic Light Scattering for clinical pathogens identification: application to early screening of Staphylococcus aureus on specific medium », E. Schultz, V. Genuer, P. Marcoux, O. Gal, C. Belafdil, D. Decq, M. Maurin, S. Morales, SPIE-10479, BIOS, San Francisco, 2019.*
- *« Optical forward-scattering for identification of bacteria within microcolonies », P.-R. Marcoux, M. Dupoy, A. Cuer, J.-L. Kodja, A. Lefebvre, F. Licari, R. Louvet, A. Narassiguin and F. Mallard, Applied Microbiology and Biotechnology, 2014, 98, 2243-2254. doi: 10.1007/s00253-013-5495-4.*

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Pierre Marcoux
pierre.marcoux@cea.fr



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MEDTECH4 EUROPE

Objectives

Medtech4 Europe gathers eight European regions willing to cooperate in improving their public policies for research and innovation facilities advancing medical technology. Main output consists of eight local action plans based on exchange of experiences, benchmarking, interregional mapping and joint analysis, study visits and workshops. The main expected result is to improve the use of structural funds for strengthening RDI medical technology ecosystems and adapting business models of RDI facilities to the needs of companies and research and for developing interregional RDI projects.

Medtech4 Europe
Interreg Europe

https://www.interregeurope.eu/medtech4europe/

Keywords
Innovation policies
Medical technology
R&D infrastructures
Regional cooperation

MEDTECH at a glance

54 months
Jun. 2018 > Nov. 2022

EC Programme
Interreg Europe

Project Coordinator
Auvergne-Rhône-Alpes Region (FR)

Partners
DE: Steinbeis-Europa-Zentrum der Steinbeis Innovation gGmbH
DK: The Capital Region of Denmark
FI: Helsinki-Uusimaa Regional Council
FR: Auvergne-Rhône-Alpes Region, CEA
HU: South Transdanubian Regional Innovation Agency Nonprofit Ltd
IT: Foundation Lombardy Cluster Technologies for Living Environment - TechForLife
NL: Province of Limburg
PL: Upper Silesian Agency for Entrepreneurship and development Ltd. (GAPR)

Total budget
€ 1.7 m.

EC Contribution
€ 1.4 m.

Contract Number

Optimizing the Impact of Public Policies in Favour of Research and Innovation Facilities in the Field of Medical Technologies

The MEDTECH project involves strengthening public policies (structural funding and regional policies) in favour of research, development and innovation facilities that advance medical technology. Eight European regions share good practices in elaborating future action plans for developing innovation ecosystems in the medical technology sector.

CEA-Leti in MEDTECH

CEA-Leti is expert partner in Europe's Medtech4 consortium. Regional authorities or their legal representatives (clusters, development agencies) possess little internal expertise in medical technology innovation issues, future prospects for medical device markets and global trends in this sector. This project's focus, specifically policy support to research, development and innovation facilities, is a key issue for CEA-Leti, which has built and commissioned two operating medtech research infrastructures, namely Clinatec and Nano-Bio in Grenoble, and has implemented technological research programmes in cooperation with the industry.

CEA-Leti provides methodological and technical assistance to the consortium based on its expertise in open innovation campuses, European medical device networks and cooperation with the medtech industry.

CEA-Leti is leading a number of project tasks:
- Definition of common methodology to benchmark 8 regional policy instruments and their specific context (State of Play)
- Benchmarking the 8 regions through Joint Cross Analysis
- Advising the consortium throughout the project.

Expected outcomes for CEA-Leti:
- Transfer of expertise in medical device innovation processes to European regions, in particular the Auvergne-Rhône-Alpes regional authority
- Understanding existing and future issues in the use of European regional development funds and territorial cooperation as experienced by regional authorities
- Planning future proposals for enhancing cooperation in a 4-part helical system (Research, Education, Industry, Public Authorities) in a European context
- Preparing regional authorities for taking part in Public Private Partnerships as a leveraging effect among EU funds and in cooperation with the medical technology industry.



© Medtech4Europe

IMPACT

Interregional cooperation and streamlined use of European regional development funds are growing trends seen in European public policies. The project will show how such cooperation has developed in a specific area: medical technology. Industry and innovation players such as research institutes will benefit from these new policies. Eight regions will invest in medical technology, each implementing its own action plan, and there will be improved networking among key regional medical technology hubs in Europe.

Françoise Charbit
francoise.charbit@cea.fr



NanoAthero

Objectives

In acute coronary syndrome and stroke, atherosclerotic plaque disruption with superimposed thrombosis is the leading cause of mortality in the Western world. The Nano-Athero project brought together 15 European research groups involved in the nanomedicine field as technology developers and clinical groups involved in cross-disciplinary research in cardio-vascular diseases in a context of growing social and health costs. Nanosystems were developed for imaging and treatment of thrombus and plaque.

- New nanoimaging agents allow non-invasive molecular imaging of key pathological processes in vulnerable plaques.
- Nanosystems are used to delivery and increase drug efficiency for plaque and stroke treatments in humans.

NanoAthero

www.nanoathero.eu

Keywords
Nanomedicine

NanoAthero at a glance

66 months
Feb. 2013 > Jul. 2018

EC Programme
FP7 NMP.2012.1.2-2 - Development and phase-I clinical trials of novel therapeutic nanotechnology-enabled systems for the diagnosis and treatment of atherosclerosis

Project Coordinator
INSERM (FR)

Partners
AT: Medical University of Graz
CH: CLINAM - European Foundation for Clinical Nanomedicine
DE: Max Planck Institute of Colloids and Interfaces, nanoPET Pharma GmbH, Universitätsklinikum Erlangen
DK: Lundbeckfonden Center of Excellence in Nanomedicine NanoCAN
FR: CEA-Leti, CEA-DSV, Hopitaux de Paris, Inserm, Inserm-Transfert SA
GB: Edinethics Ltd
HU: Semmelweis University
IL: WinzSoft
IT: Bracco Imaging S.p.A
NL: Academic Medical Center, University of Twente

Total budget
€ 12.8 m.

EC Contribution
€ 9.8 m.

Contract Number
309820

Nanomedicine for target-specific imaging and treatment of atherothrombosis

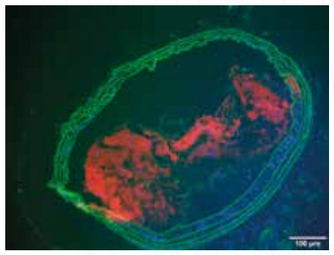
With more than 6 million new cases of Cardio-Vascular Disease (CVD) in the EU every year, the disease remains the leading cause of mortality and the major cause of morbidity in Europe. Nano-Athero aims to establish the preliminary clinical feasibility of implementing nanosystems for targeted imaging and treatment of advanced atherothrombotic disease in humans.

CEA-Leti in NanoAthero

On the strength of its extensive previous experience in the nanomedicine field and, specifically, its proprietary know-how involving lipid-based nanoparticles, CEA-Leti completed 3 main technical Nano-Athero project tasks:

- Development of 64Cu-B22280-F50, a new contrast agent for atherosclerotic plaque detection based on PET (Positon Emitting Tomography) imaging, which is one of the two sensitive imaging modalities for use in cardio-vascular treatment clinics
- Development and implementation of mid-scale 64Cu-B22280-F50 production to prepare a clinical translation phase (i.e. a production process that is ready to use for clinical trials in a GMP environment)
- Investigation of lipid-based nanoparticles as drug carriers for treating atherosclerotic plaques.

The nanometric size and natural affinity for lipid-rich areas enabled **demonstration of CEA-Leti lipid-based nanoparticles (Lipidots™ technology) in efficiently and specifically targeting atherosclerotic plaques in rat animal models; their injection proved to be very safe.** In comparison with currently investigated and reported clinical methods using recombined engineered lipoproteins, the CEA-Leti synthetic approach, based on natural or semi-synthetic products, ensures a better controlled, simpler and cheaper manufacturing process. Lipid-based nanoparticles are therefore of prime interest in further research into atherosclerosis diagnosis and could also be promising for long-term treatment of atherosclerotic plaque, when suitable, efficient drugs are identified.



Screening of drug-loaded lipid nanoparticles for plaque treatment demonstrated in ApoE mouse model.
© Medical University of Graz

IMPACT

In the context of growing social and health costs of cardiovascular diseases, the Nano-Athero project's main outcome was launching of a phase 1 clinical trial on one nano-based contrast agent for atherosclerotic plaque detection. Two other nanosystems (including that of CEA-Leti) have been identified as promising for plaque imaging and therapy during preclinical experiments. These will now commence the long process involving the regulatory studies required for preparing clinical trials.

Publications

- *«From Design to the Clinic: Practical Guidelines for Translating Cardiovascular Nanomedicine», I. Cicha, C. Chauvierre, I. Texier, C. Cabella, J.- M. Metselaar, J. Szebeni, C. Alexiou, F. Rouzet, G. Storm, E. Stroes, D. Bruce, N. MacRitchie, P. Maffia, D. Letourneur, Cardiovasc Res. 114(13), 1714-1727, doi: 10.1093/cvr/cvy219 (2018).*
- *«Comparative analysis of nanosystems'effects on human endothelial and monocytic cell functions», J. Matuszak, P. Dörffler, S. Lyer, H. Unterweger, M. Juenet, C. Chauvierre, A. Allarg, D. Franke, G. Almer, I. Texier, J.-M. Metselaar, R. Prassl, C. Alexiou, H. Mangge, D. Letourneur, I. Cicha, Nanotoxicology 28:1-18, doi: 10.1080/17435390.2018.1502375 (2018).*
- *«Nanoparticles for intravascular applications: Physicochemical characterization and cytotoxicity testing», J. Matuszak, J. Baumgartner, J. Zaloga, M. Juenet, A. Eduardo da Silva, D. Franke, G. Almer, I. Texier, D. Faivre, J.-M. Metselaar, F.-P. Navarro, C. Chauvierre, R. Prassl, L. Dézsi, R. Urbanics, C. Alexiou, H. Mangge, J. Szebeni, D. Letourneur, I. Cicha, (NanoAthero Consortium), Nanomedicine, Vol. 11, No. 6, Pages 597-616, March 2016.*
- *«Nanostructured lipid carriers accumulate in atherosclerotic plaques of ApoE–/– mice», J. Vigne, C. Cabella, L. Dézsi, E. Rustique, A.-C. Couffin, R. Aid, N. Anizan, C. Chauvierre, D. Letourneur, D. Le Guludec, F. Rouzet, F. Hyafil, T. Mészáros, T. Fülöp, J. Szebeni, A. Cordaro, P. Oliva, V. Mourier, I. Texier, Nanomedicine: Nanotechnology, Biology, and Medicine 25, 102157 DOI : 10.1016/j.nano. 2020.102157 (2020).*
- *«Novel Nanosystems to Combat Atherosclerosis: Functional Effects on Endothelial and Monocytic Cells», I. Cicha, J. Matuszak, M. Juenet, C. Chauvierre, I. Texier, G. Almer, R. Prassl, J.M. Metselaar, L. Dézsi, R. Urbanics, J. Szebeni, C. Alexiou, H. Mangge, D. Letourneur, European Society of Cardiology Congress 2016 was published on Thursday 13th October in EMJ Cardiology 4.1, Rome, 27-31 August 2016.*
- *«Biodistribution of Nanostructured Lipid Carriers in Mice Atherosclerotic Model», L. Devel, G. Almer, C. Cabella, F. Beau, M. Bernes, P. Oliva, F. Navarro, R. Prassl, H. Mangge, I. Texier, Molecules 24, 3499, doi:10.3390/molecules24193499 (2019).*

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Isabelle Texier-Nogues
isabelle.texier-nogues@cea.fr



Nareb

NAREB
Nanotherapeutics for Antibiotic Resistant Emerging Bacterial pathogens

http://www.nareb.eu/

Keywords
Antibiotics
Antimicrobial resistance
Nanomedicine

Nareb at a glance

48 months
Jan. 2017 > Jul. 2018

EC Programme
NMP.2013.1.2-2

Project Coordinator
Institut Pasteur (FR)

Partners
BE: Coris bioConcept
DE: Forschungszen trom Borstel
ES: GlaxoSmithKline, Nanoimmunotech, University of Zaragoza
FR: CEA-Leti, Inserm transfert, Institut Pasteur, IRT BioAster
GB: KU, National Institute for Biological Standards and Control, University of East Anglia
NL: University Utrecht
NO: Stiftelsen Sintef
PL: National Medecine Institute

Total budget
€ 13 m.

EC Contribution
€ 9.7 m.

Contract Number
604237

Nanotherapeutics for Antibiotic Resistant Emerging Bacterial pathogens

The NAREB project aimed to counter greater antimicrobial resistance through the use of innovative nanoparticles that deliver antimicrobial agents to infected tissues.

Objectives

Increase in antimicrobial resistance is a global concern. The portfolio of available antimicrobial drugs for treating resistant bacterial infections is very limited and comprises molecules inducing severe side effects and/or that are difficult to administrate. New drugs or at least new formulations of known drugs that offer enhanced efficiency are urgently needed for faster, more efficient and less impairing treatment.

In this context, the NAREB project proposed nanotechnology solutions to the problem of Multi-Drug Resistant (MDR) tuberculosis (TB) and Methicillin Resistant Staphylococcus Aureus (MRSA) infections, two well-known drug resistant bacterial diseases causing major public health problems in both developed and developing countries.

NAREB brought together 16 partners from 8 EU Member and Associated States with outstanding complementary expertise, ranging from material engineering to molecular biology, pharmacology, microbiology and medicine. This association was instrumental for confirming the possibility of associating several antibiotics with nanoparticles without loss of efficiency. No superiority in the efficiency of antibiotics combined with nanocarriers was demonstrated, but no toxicity was observed at concentration used for antibiotic treatment in free antibiotics. Additional studies will be necessary to investigate the superiority of antibiotics combined with nanocarriers in relation to reducing side effects in the long term.

The most successful outcome was development of two new diagnostic systems that can rapidly detect MRSA and MDR-TB from clinical specimens with sufficient sensitivity and specificity. These products will have a major impact on society and the economy; they are expected to reach the market very soon.

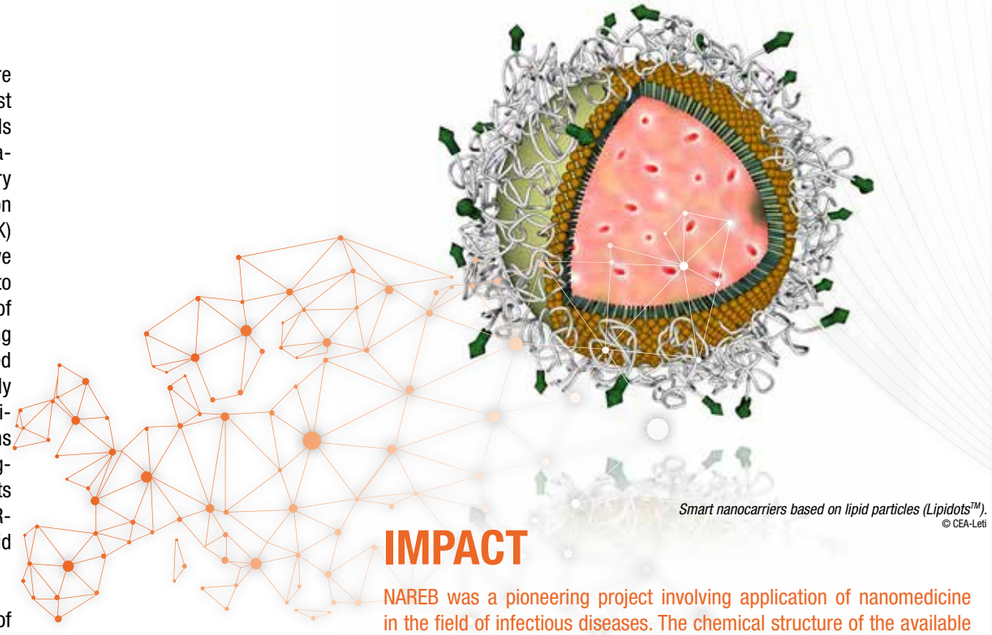
The World Health Organization (WHO) has recognized antibiotic resistance as one of the three major threats to global health and is indeed predicting a forthcoming disaster due to its rapid, unchecked growth mainly because of the paucity of new classes of antibacterials being developed. Nanotherapeutics may greatly contribute this major health-related socio-economic and societal challenge by providing new approaches to combat resistant bacteria, hence improving the patient quality of life and reducing related healthcare costs. Applications of nanoformulation of antimicrobial agents may be easily extended to treat other infectious diseases.

CEA-Leti in Nareb

Preparing drug-loaded nanoparticles with antimicrobial activity

Within the NAREB project scope, multiple candidates (drug-loaded nanoparticles) were produced for M. tuberculosis and S. aureus. Their stability and characteristics were first investigated on each nanoparticle platform. The transcriptional response of human cells to nanoparticle treatment was also investigated. We studied the feasibility of encapsulating various antimicrobial agents countering MDR-TB or MRSA in four different delivery systems including nanostructured lipid carriers manufactured by CEA-Leti. Transcription factor decoy molecules in self-assembled bola amphiphilic-based particles (Procarta, UK) were also considered for a time only because results were contradictory. The respective particle preparation processes were optimized in relation to the required quantities and to sterility and purity. A decision tree was drawn up to accelerate and rationalize selection of relevant candidates to be considered for further in vivo testing in animal models including key criteria such as the drug payload, stability, activity and safety of tested drug-loaded particles. This process allowed us to test a large number of possible combinations (initially 289 and 258 for MDR-TB and MRSA respectively) and to identify 5 and 3 promising candidates for MDR-TB and MRSA respectively. For these candidates, the adapted formulations after spray-drying were prepared, within the project scope, for parental injection of drug-loaded particles and for the quantities required for in vivo assays. The in vivo experiments involved acute and chronic assays in animal models of infectious diseases for either MDR-TB or MRSA. We demonstrated that antibiotic delivery was greatly enhanced by using lipid nanoparticles in the diseased tissues (lung and blood).

However, this did not correlate with really higher efficiency in reducing the number of bacterial colonies in the infected tissues. A deeper safety assessment may be relevant to demonstrate significant improvement in the efficiency/safety balance by reducing antibiotic side effects in other organs; these experiments were not performed within the NAREB scope.



Smart nanocarriers based on lipid particles (Lipidots™).
© CEA-Leti

IMPACT

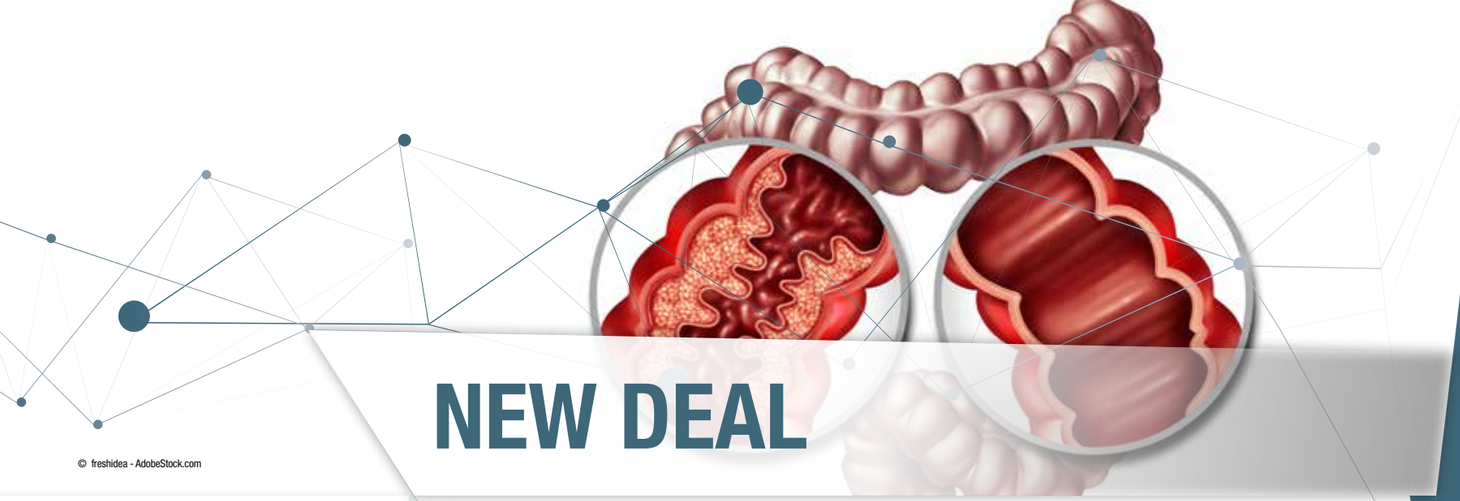
NAREB was a pioneering project involving application of nanomedicine in the field of infectious diseases. The chemical structure of the available antibiotics implies that these drugs' doses need to be high (mg range) to make them really efficient. The principle of delivering using synthetic nanoparticles has been demonstrated and validated in animal models. However, this concept could be more relevant when applied to antimicrobial agents with better activity, such as biomacromolecules (peptides, proteins or nucleic acids). The lessons learned from NAREB were very helpful in improving nanomedicinal product manufacturing and targeting therapeutic applications.

Publications

«New active formulations against M. tubercolosis: Bedaquiline encapsulation in lipid nanoparticles and chitosan nanocapsules», De Matteis L. et al., Chemical Engineering Journal, 2018, 107:181-191. A. Hibbitts, A. Lucia, I. Serrano-Sevilla, L. De Matteis, M. McArthur, J.M. De La Fuente, J.A. Ainsa, F. Navarro, Co-delivery of free vancomycin and transcription factor decoy-nanostructured lipid carriers can enhance inhibition of methicillin resistant Staphylococcus aureus (MRSA) (2019) PLoS ONE, 14 (9), art. no. e0220684.

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Fabrice Navarro
fabrice.navarro@cea.fr



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NEW DEAL

Objectives

The NEW DEAL project aims to develop a new therapeutic strategy for inflammatory bowel diseases (IBDs), the most common immune disorders in young adults in Europe (affecting about 2.3-3 million people) with an increasing incidence. Conventional and biological therapies using anti-inflammatory drugs and/or specific antibodies targeting TNF- still leave a significant number of IBD patients insufficiently treated. The NEW DEAL therapeutic strategy relies on several innovations in the biomedical field. Therapeutic molecules will be specific siRNAs allowing a specific, sensitive inhibition of new molecular targets (targeted medicine) and thesenovel bio-therapeutics vulnerable to enzymatic degradation in biological environment will be delivered to the inflamed gut through smartly designed lipid nanoparticles offering protection and transport across biological barriers (nanomedicine). If successful, NEW DEAL will have a beneficial impact on the quality of life of many IBD patients and will markedly reduce the IBD-related costs. In NEW DEAL, the new bio-therapeutics (siRNA targeting some kinases) and their delivery technologies will be designed and validated at preclinical level using the most relevant models of biological barriers and/or experimental colitis. This will allow us to prepare future clinical translation by taking into account all the regulatory requirements.

https://newdeal-project.eu/

Keywords
Biological barriers
Biological therapies
Inflammatory bowel diseases
Lipid nanoparticles
Nanomedicines
siRNA therapies

NEW DEAL at a glance

48 months
Jan. 2017 > Jan. 2021

EC Programme
Horizon 2020 research and innovation programme

Project Coordinator
CEA-Leti (FR)

Partners
BE: Eurofins SEPS pharma, Prodigest
DE: ERS, HIPS
ES: Institut d'Investigacions Biomèdiques August Pi i Sunyer, NIT, Science seed
FR: Inserm, Mayoli Spindler
GB: Boyd Consulting

Total budget
€ 6 m.

EC Contribution
€ 6 m.

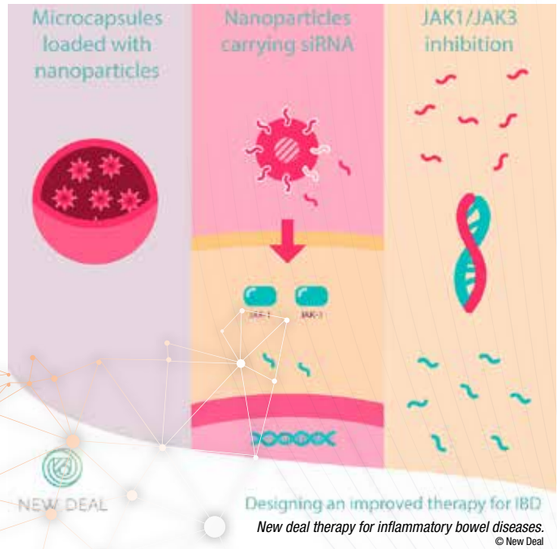
Contract Number
720905

New siRNA Nanotherapy for Inflammatory Bowel Diseases, targeting Janus kinase 1 and 3

The aim of the NEW DEAL initiative is to design the next generation of biological therapy for inflammatory bowel diseases. These immune disorders of the gut, including Crohn's disease and ulcerative colitis, are chronic with an early onset in life, typically in adolescents and in young adults. These diseases decrease quality of life and can lead to life threatening complications (bowel perforation, cancer...). The efficiency of currently available drugs, including steroids and immunosuppresses, as well as antibody-based therapies (anti-TNF approach) remains suboptimal for a large proportion of patients. The need of novel therapies persists in this context. Our concept is to develop a new targeted therapy for the inflamed gut based on using siRNA (the next generation of biological drugs after antibodies) to target and inhibit expression of proteins involved in inflammation cascades (janus kinases) and on a delivery system capable of supplying these nucleic acids to the immune cells at the colon level.

CEA-Leti in NEW DEAL

CEA-BIG has designed siRNA sequences targeting human JAK1, human JAK3, murine JAK1 and murine JAK3 and has validated their specific characteristics based on in vitro models. The selected sequences lead to a very high regulation efficiency without observing off-target effects or unwanted Toll-like receptor activation to date. Investigations are ongoing to study the phenotypic outcomes on silencing. In parallel, CEA-Leti has designed and prepared nanostructured lipid carriers to transport siRNA biomolecules. These particles exhibited very high colloidal stability and a good safety profile. We have validated their compatibility with formulation preparation processes for human administration (rectal and/or oral dosage forms) such as spray drying or spray coating on solid carriers. Models of mucus and intestinal epithelium have been built. The capacity of particles and siRNAs to cross these biological barriers under inflammatory conditions is still under investigation. In addition, first biodistribution studies in rodent models of experimental colitis have given encouraging preliminary results with lipid particles being detected in some cell subpopulations from the inflamed gut. The stability of nanocomplexes (siRNA loaded lipid nanoparticles) in very complexe colonic media is still under evaluation and optimization , yet major achievments were already completed. A first draft of the clinical development plan has been prepared and the main regulatory requirements have been identified and shared with the consortium.



New deal therapy for inflammatory bowel diseases.
© New Deal

IMPACT

siRNA therapeutics have been insufficiently investigated in the context of inflammatory bowel diseases. Compared with therapeutic antibodies, they offer new possibilities for targeted medicines with good control of immunogenicity and bioavailability, when delivered by appropriate carriers. This is of a great interest, especially since relevant molecular targets in IBDs have been recently identified in clinics along with promising outcomes using chemical inhibitors. However, the lack of specific characteristics and their systemic effects hamper the clinical approval of these approaches. siRNA therapeutics have the potential to overcome these limitations. Local delivery can be achieved through the use of smart carriers. So far, no carrier has been clinically approved for delivering biomolecules across the intestinal barrier. If successful, the NEW DEAL project team will design and validate such a carrier at the late preclinical stage. The nanostructured lipid carriers developed in NEW DEAL offer multiple advantages with the prospect of future clinical translation and industrial transfer in terms of manufacturing processes, stability and safety. siRNA therapeutics and lipid carriers could have significant economic impacts even beyond the IBD context.

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Fabrice Navarro
fabrice.navarro@cea.fr

Dorothée Jary
dorothee.jary@cea.fr



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NOBEL

https://nobel-project.eu/

Keywords
Coordination
Ecosystem
Innovation
International cooperation
Key enabling technologies
Medical technologies
Nanomedicine
Network
Open innovation
Roadmapping
Start-ups
Training
Translation

NOBEL at a glance

36 months
Nov. 2017 > Sep. 2020

EC Programme
H2020-NMBP-2016-2017/
H2020-NMBP-CSA-2017

Project Coordinator
ETPN (FR)

Partners
BE: Medetch-Europe
DE: Bioanalytik-muenster,
VDI-VDE Innovation + Technik
FR: CEA-Leti, ETPN Association
IE: University College Cork
IT: Don Carlo Gnocchi
PT: TechMinho

Total budget
€ 2 m.

EC Contribution
€ 2 m.

Contract Number
766492

Mobilising the European Nanobiomedical ecosystem

NOBEL embodies coordination and support action designed to build a unique European ecosystem to ensure convergence of nanomedicine and other emerging medical technologies.

CEA-Leti in NOBEL

As Chairman of the European Technology Platform on Nanomedicine (ETPN), CEA-Leti is co-coordinating the NOBEL project. ETPN represents the focal point for European Community stakeholders in the field of nanomedicine. NOBEL has initiated development of a joint vision on health technologies with contributions from other European technology platforms developing key technologies for health such as photonics, advanced materials, biomaterials, smart systems and robotics.

NOBEL has consolidated a joint strategic vision on nanomedicine with all six contributing national platforms.

A meta-roadmap on technologies for healthcare is being established that will contribute to the Strategic Research Agenda on Health under Horizon Europe.

In just one year, 23 companies have been supported by the NOBEL Healthtech Translation Advisory Board in their translation from laboratory to market.

Objectives

To compete globally, Europe must innovate and develop nanomedicines and medical technologies with high value and high technological content, well protected IP and ensuring a clinical need and commercial opportunities of all new innovations. Technically, this will be achieved by combining elements of key enabling technologies including nanotechnologies, photonics, robotics, advanced materials and information technologies to produce smart medical devices and smart nanomedicines. However, translation of preclinical proof of concepts to the market via clinical validation, regulatory approval and approval for reimbursement by the healthcare systems, requires a more integrated and streamlined ecosystem with less barriers between stakeholders and steps. Following their outstanding 12-year experience in developing nanomedicine and medical technologies, European Technology Platform on Nanomedicine (ETPN) and its seven NOBEL partners are merging their networks to set up a coherent, robust and unique ecosystem, in which information flow will improve awareness throughout the value chain and right up to market access. NOBEL develops interactions, cooperation and implementation of complementary actions at local, regional, national, European and even international levels. Building this ecosystem is based on two main pillars: a joint vision of strategy or future (roadmapping) and strong cohesion and interrelationship among ecosystem members. One of the most significant and impactful outputs of this inclusive efficient ecosystem is the tangible acceleration of development and industrialization of innovative SMEs in nanomedicine and medical technologies. This will impact the EU economic renaissance by creating jobs and value in Europe. NOBEL will be unique in building the most efficient network of connections and synergies throughout the value chain of nanomedicine and healthcare technologies in Europe.



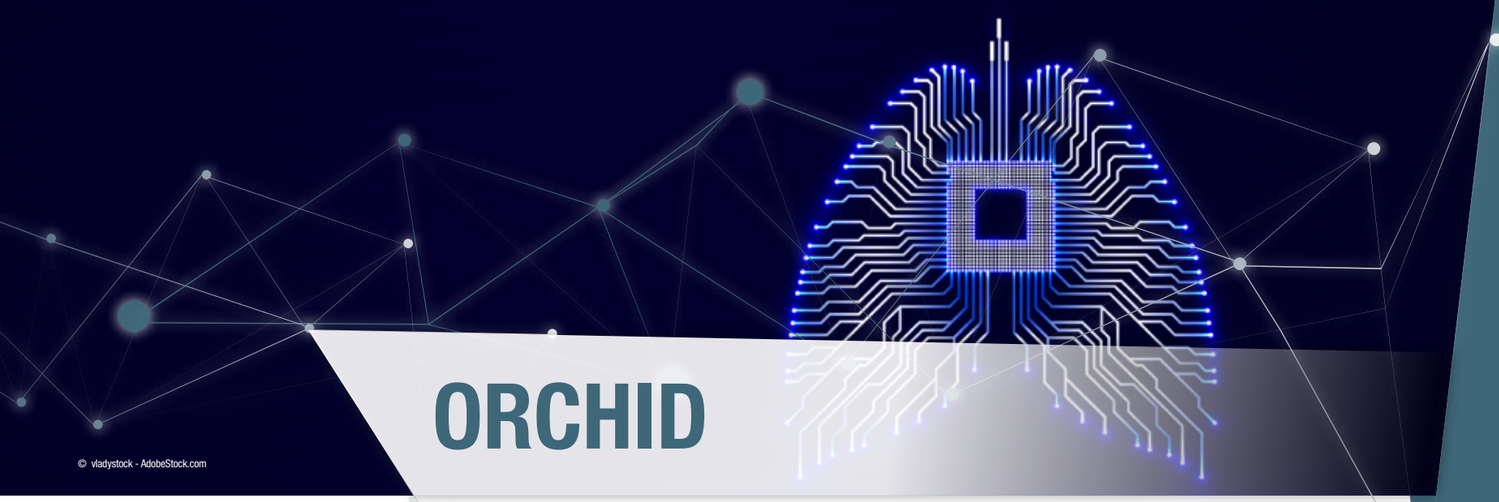
Mentoring by industry expert at Healthtech TAB event.
© NOBEL

IMPACT

- Increased take-up of innovative nanomedicine and emerging medical technology solutions by industry and SMEs, end-users, regulatory and public authorities, healthcare insurances, doctors and patients, research organizations and academia
- Improvement of cross-KETs activities to provide better integrated smart healthcare solutions
- Increased international networking with new potential market opportunities
- Global improvement in the competitiveness of Europe's healthcare research.

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Françoise Charbit
francoise.charbit@cea.fr



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ORCHID

Objectives

Organ-on-chip technology will revolutionize the healthcare domain by offering new, ground breaking solutions to different industries, especially in regenerative medicine and medication.
ORCHID have achieved this through its 5 objectives:

- Evaluate existing technology (state of the art and unmet needs)
- Identify ethical issues, establish standards and identify measures for regulatory implementation
- Analyze economic and social impact, training and education
- Develop a roadmap for guiding required R&D efforts
- Raise awareness and build an ecosystem for organ-on-chip technology using a digital reference platform (Creation of the European Organ-on-Chip Society EUROoCS).

Organ-on-Chip In Development

The main goal of the ORCHID project is to create a roadmap for organ-on-chip technology and to build a network of all relevant stakeholders in this promising innovative field. Seven leading European research institutions are actively committed to the ORCHID project since its inception on 1st October 2017.

https://h2020-orchid.eu/

Keywords
Disease model
Microfluidics
Organ
Organ-on-chip
Tissue

ORCHID at a glance

24 months
Oct. 2017 > Sep. 2018

EC Programme
H2020-EU.1.2.1. - FET Open

Project Coordinator
Leiden University Medical Center (NL)

Partners
BE: IMEC
DE: Fraunhofer
ES: Zaragosa University
FR: CEA-Leti
NL: Delft University, Human Organ and Disease Model Technologies, Leids Universitair Medisch Centrum

Total budget
€ 0.5 m.

EC Contribution
€ 0.5 m.

Contract Number
766884

CEA-Leti in ORCHID

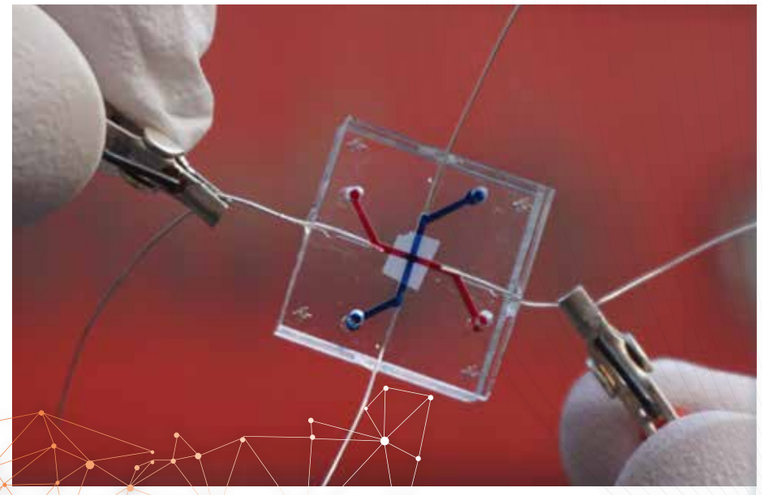
CEA-Leti has taken part in a bibliometric study, market analysis, expert interviews and panel discussions to survey the current landscape in research, development, applications and market opportunities for Organ-on-Chip (OoC) devices in order to build the foundations of a European OoC ecosystem. The report on these actions outlines the existing unmet needs, key challenges, barriers and perspectives in the field. It proposes recommendations for designing a European roadmap that could transform OoC systems (OoCs) into realistic models of human (patho)physiology in the near future.

Synergy-based convergence of microfabrication technologies and tissue engineering makes OoCs promising tools for realistic modeling of human physiology and pathology. The aim of an OoC is not to replicate a whole living organ but to sustain a minimum functional (sub) unit of an organ or tissue that can controllably recapitulate the salient aspects of human physiology.

For this purpose, the main and desired features of an OoC can be divided into three categories:
Tissue architecture:
- Integrated long-term cell culture in defined spatial organizations
- Tissue-tissue interfaces/cell-cell contacts/cellular heterogeneity
- Miniaturization.

Conditions:
- Controlled microenvironment (topology, biochemistry, physics)
- Controlled dynamics (fluid flow, electro-mechanical stimuli)
- Continuous automated perfusion
- Real-time monitoring of multiple physical, bio- and electro-chemical parameters
- Automated reproducible multi-sample analysis, comparable or compatible with R&D robotics
- Large-scale manufacturability.

Functions:
- Physio- and pathological relevance
- Recapitulation of organ structure and function
- Recapitulation of dynamic mechanical biological properties and stimuli response of organs.



Lab on a chip.
© Paul ter Braak/Marinke van der Helm; BIOS Lab on a Chip group, UTwente

IMPACT

ORCHID will have a broad impact: it will facilitate drug development, contribute significantly to reducing animal experiments and help in developing personalized medicine. The project will achieve these goals by providing a framework for principal stakeholders, bringing together key players and raising awareness of organ-on-chip technology throughout Europe.

Publications

- *«Organ-on-Chip In Development: Towards a European roadmap for Organ-on-Chip», M. Mastrangeli, S. Millet, D. Braeken, W. Eberle, L. Fernandez, M. Graef, X. Gidrol, N. Picollet-D'Hahan, P. Loskill, C. Mummery, I. Ochoa, M. Schutte and J. van den Eijnden-van Raaij, Workshop report, ALTEX 36(4), 2019.*
- *«Building Blocks for a European Organ-on-Chip Roadmap», M. Mastrangeli, S. Millet, Chr. Mummery, P. Loskill, Dr. Braeken, W. Eberle, M. Cipriano, L. Fernandez, M. Graef, X. Gidrol, N. Picollet-D'Hahan, B. van Meer, I. Ochoa, M. Schutte and J. van den Eijnden-van Raaij, Workshop Report, ALTEX 36(3), 2019.*
- *«Organ-on-Chip In Development: ORCHID Final Report», M. Mastrangeli, S. Millet, Chr. Mummery, P. Loskill, Dr. Braeken, W. Eberle, M. Cipriano, L. Fernandez, M. Graef, X. Gidrol, N. Picollet-D'Hahan, B. van Meer, I. Ochoa, M. Schutte and J. van den Eijnden-van Raaij, final report, 2019.*

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Remco den Dulk
remco.dendulk@cea.fr



PANBioRA

https://www.panbiora.eu/

Keywords
Biomaterial-tissue interactions
Cytotoxicity
Genotoxicity
Immune response
Microbiota
Microfluidics
Modeling
Personalised risk assessment
Real-time monitoring
Standardization

PANBioRA at a glance

48 months
Jan. 2018 > Dec. 2021

EC Programme
NMBP-12-2017
Nanotechnologies, Advanced Material, Biotechnologies and Production

Project Coordinator
Engin Vrana, Spartha Medical, (FR)

Partners
ALB: Turgut Ozal Education SHA
BE: Centre Hospitalier Universitaire de Liège, Pro-Active
CZ: Biodevice Systems s.r.o.
DE: Steinbeis 2i Gmbh, Steinbeis R-Tech
EE: Protobios OU
ES: Agencia Estatal Consejo Superior de Investigaciones Científicas
FI: Aalto-Korkeakoulusaatio
FR: INSERM UMR 1121, Elvesys
GB: University of Nottingham
IR: Dolmen Design and Innovation Ltd., Dublin City University
RS: SteinBeis Advanced Risk technologies Institute doo Kragujevac

Total budget
€ 8 m.

EC Contribution
€ 8 m.

Contract Number
760921

Personalised And/or Generalised Integrated Biomaterial Risk Assessment

Biomaterial-based solutions are used in various healthcare system applications. However, current available methodologies are insufficient for accurate risk assessment of all biomaterial applications. The aim of the PANBioRA project is to provide a set of tools for standardizing assessment of new biomaterials.

CEA-Leti in PANBioRA

The aim of PANBioRA project is to design a complete solution for biomaterial biocompatibility testing. This relies especially on cell culture and micro-organ monitoring using a set of sensor integrated in microfluidic platforms. **CEA-Leti is leader of the Work package dedicated to developing the µfluidic (bio)sensing platform.** This equipment integrates different (bio)sensors that enable real-time detection of metabolic species generated by stressed cells, sequential detection of protein biomarkers (cytokines or chemokines) and characterization of cell aggregation/tissues. CEA-Leti is developing the complete µfluidic platform, which includes:

• Designing the overall microfluidic system integrating a cell culture system, a microfluidic chamber for metabolite electrochemical monitoring and a µfluidic chip dedicated to optical detection of chemokines and cytokines

• Designing a fully biocompatible electrochemical sensing platform integrating reactive oxygen species (NO and H2O2) electrochemical sensors, a pH potentiometric sensor and a lactate enzymatic biosensor

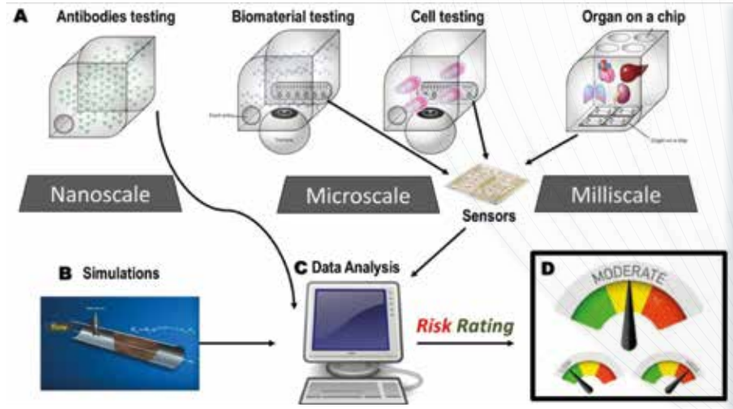
• Designing impedance electrodes for cell tissue characterization.

CEA-Leti is currently recognized for his capabilities in designing µfluidic systems and multiparametric (bio)electroanalytical platforms for diagnosis and life sciences. However, implementation of multiparametric sensing platforms within µfluidic systems for cells and micro-organs remains poorly developed. PANBioRA is prompting the CEA-Leti team to develop innovative electrochemical sensor technologies for these highly demanding applications. This should position CEA-Leti as European leader in the field of instrumented µfluidic systems and their application to cell culture and organ-on-chip. These developments also open up the way to designing fully biocompatible electrochemical sensing platforms that may be more closely involved in instrumented implanted prosthesis.

Objectives

PANBioRA aims at providing customized pre-implantation diagnostics for biomaterial-based applications to ensure better clinical outcomes and minimize risks associated with the use of established and new biomaterials. A generalized, standard testing system can provide not only more information on new biomaterials, but also the extensive data needed to develop an understanding of human-biomaterial interactions at the biological systems level. Interaction and exposure to specialized biomaterials is a relatively new occurrence for the mammalian immune system and the capacity to predict future risks is strongly dependent on the capacity to collect and evaluate data on the cell-material interface as PANBioRA ensures.
Current tests involve manual handling, which is subject to low throughput and possible human error. PANBioRA takes these human factors into account to design an integrated, user-friendly system. This system refers to a series of integrated/connected test modules and instruments, supplemented by data analysis, modelling, and radar risk components. The main objective of the project is to develop a modular and integrated system to allow the evaluation of biomaterial domains including:
• A new biomaterial for health or disease condition (generalized test) or
• A given biomaterial for a specific patient (personalized test).
To achieve this objective, the PANBioRA team is developing a user-friendly platform that can provide superior risk assessment for new (polypeptide/artificial polysaccharide materials) and existing (silicones, titanium, gelatin and their 3D printed shapes) materials at different levels and lengths, including:
• Antibody response, cytotoxicity/genotoxicity at the cellular level
• Systemic and local effects at related tissue and tissue levels
• Risks to the environment and degradation at physical chemical and biomechanical levels
• Predictive modelling at system level (including microbiota responses).

This will be achieved through the simultaneous evaluation of host-biomaterial interactions involving nanoscale to micrometer scale effects and will result in four enabling tools:
• A PANBioRA integrated biomaterial assessment instrument
• Expansion of the improved simulation test on biomaterials (for biomechanical characterization)
• Web-based biomaterial modelling systems (for microbiota responses, degradation kinetics, and toxicity in 3D environments) and
• A risk radar available on the Web.



Modular components of PANBioRA system. Microfluidic integration of the whole system combined with real-time monitoring with electrochemical sensors, mini-microscopes and data-fitting will provide several magnitudes of more information with less biomaterial samples, smaller biological samples and smaller amounts of consumables.
©CEA-Leti

IMPACT

The PANBioRA project is generating technical impacts through implementation of an integrated system capable of performing biomaterial analyses complying with the relevant standards at different length scales and for providing an assessment based on a specially developed rating system. The economic impacts can be evaluated by developing new products and discoveries at a fraction of the cost of currently mandated standards (industrial) and a way to make more informed decisions on the choice of customizable implantable materials (health).

Publications

«Elastic Light Scattering for clinical pathogens identification: application to early screening of Staphylococcus aureus on specific medium», E. Schultz, V. Genuer, P. Marcoux, O. Gal, C. Belafdil, D. Decq, M. Maurin, S. Morales, SPIE-10479, BIOS, San Francisco, 2019.

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Véronique Mourier
veronique.mourier@cea.fr



REFINE

Objectives

REFINE proposes a Regulatory Science Framework for the risk-benefit assessment of medical products and medical devices that are based on nanotechnologies and biomaterials. The core of the framework is development of a product-specific Decision Support System that identifies the most efficient way to deliver the data required by the relevant regulation using best fitting methods. The decision tree can identify the product's specific regulatory issues and the priorities of both missing data and missing methods meeting these issues. Subsequently, it allows planning of a cost and time, efficient strategy for taking necessary measurements and progressing the best fitting methods. Our approach is aligned with the industrial R&D practice of stage gating.
The framework relevance for the most pressing regulatory issues can be demonstrated. These challenges include borderline products, nanosimilars and products combining several functionalities. We have identified the regulatory issues with European and foreign regulatory authorities as well as design methods for tiered decision tree building in line with contemporary scientific knowledge. Work has been performed on the analysis and prediction of the physiological distribution of nanomedicines and biomaterials and we have developed and validated the new analytical or experimental methods and assays required by the regulators. These developments have been achieved in a quality management system, ensuring possible standardization of our assays.
REFINE brings together a wide community of stakeholders in regulation, industry, science, technology development, patients and end-users in a Consortium for the Advancement of Regulatory Science in Biomaterials and Nanomedicine.

http://refine-nanomed.com/

Keywords
Assays
Biomaterials
Decision Support System (DSS)
International cooperation,
Knowledge Base
Medical Devices
Medicinal innovation
Nanomedicine
Regulation
Regulatory framework
Risk assessment

Regulatory Science Framework for Nano(bio)material-based Medical Products and Devices

REFINE is a Research and Innovation Action to refine the current regulatory scientific framework for nano(bio)material-based medicinal products and medical devices. It will identify, design and test new characterization assays for enhanced regulatory assessment of innovative nanomedicines and biomaterials.

REFINE at a glance

55 months
Oct. 2017 > Nov. 2021

EC Programme
H2020-NMBP-2017 two-stage

Project Coordinator
CEA-Leti (FR)

Partners
CH: Empa
DE: Bioanalytik-muenster, European Research Services
ES: Biopraxis research
FR: Amatsi Group, CEA-Leti
GB: University Brighton, University Liverpool
IE: Trinity College
IT: European Commission-Joint Research Center, Green Decision
NO: Stiftelsen Sintef
NL: Rijksinstituut voor Volksgezondheid en Milieu

Total budget
€ 8 m.

EC Contribution
€ 8 m.

Contract Number
761104

CEA-Leti in REFINE

CEA-Leti is coordinating the project and is aligning its development with results obtained within EUNCL infrastructure, which also coordinated by CEA-Leti.

The aim is to develop characterization assays to improve preclinical characterization of nanomedicines and better comply with the requirements of regulators in terms of assessing the safety of these nanomedicines before granting authorization for clinical trials.
CEA-Leti is also coordinating the work package on community bridging because of its extensive European network of partners and collaborators in nanomedicine across areas of science, technology, industrialization, regulation, standardization and beyond: food, cosmetics, medical devices and nano safety.

Our Institute provides and develops new physical characterization assays for adaptation to the needs expressed by regulators and with the quality required for a future standard development and submission.

CEA-Leti produces and supplies Lipidots(r) as one of the relevant materials (a reference material) to be used for the qualification and validation of new or existing characterization assays in response to regulatory needs.



December 12th-13th 2018 Refine General Assembly Meeting Dübendorf Switzerland.
© Refine

IMPACT

REFINE will place Europe at the forefront of regulation and risk-benefit assessment of medicinal products and medical devices based on nanotechnologies and biomaterials.

The project will adjust preclinical characterization assays to the unmet medical requirements expressed by regulators.

It will deliver a Decision Support System to guide nanomedicine developers and regulators in preparing the regulatory documentation and performing preclinical characterization.

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Simon Baconnier
simon.baconnier@cea.fr



SOLUS

SOLUS | SMART OPTICAL AND ULTRASOUND DIAGNOSTICS OF BREAST CANCER

http://www.solus-project.eu/#

Keywords
Biomedical optics
Biophotonics
Breast cancer
Diffuse optics
Health-related biotechnology
Image and data processing
Non-invasive diagnostic
Oncology
Photonics
Ultrasonics
Time of flight

SOLUS at a glance

54 months
Nov. 2016 > Avr. 2021

EC Programme
H2020-ICT-2016-2017 / RIA

Project Coordinator
Politecnico Di Milano (IT)

Partners
AT: European Institute for Biomedical Imaging Research
DE: iC-Haus GmbH
FR: CEA-Leti, SuperSonic Imagine, Vermon SA
GB: University College London
IT: Micro Photonic Device S.R.L., Ospedale San Raffaele SRL, Politechnico di Milano

Total budget
€ 3.8 m.

EC Contribution
€ 3.8 m.

Contract Number
731877

Smart Optical and Ultrasound Diagnostics of Breast Cancer

Early diagnosis of breast cancer is crucial for success of the therapy. The SOLUS project aims to improve detection of tumors by building a prototype that combines standard ultrasound imaging with emerging time-resolved optical tomography. The prototype will be demonstrated in clinics.

CEA-Leti in SOLUS

• CEA-Leti is ensuring design of the new system, integration of the bimodal probe and assembly of the full prototype in terms of hardware and software. **Comprehensive specifications has been iteratively consolidated to suit the expectations of the three partners acting as project clients:** high flexibility for research purposes, conformity to medical workflow, and production of sustainable results to support an industrial strategy.

• The multimodal probe has been built from a standard ultrasound probe for breast cancer diagnosis and fitted with height smart optodes – a novel photonic component developed by the project partners. During development, **CEA-Leti has worked closely with the industrial partners** on safety issues and integration of subparts.

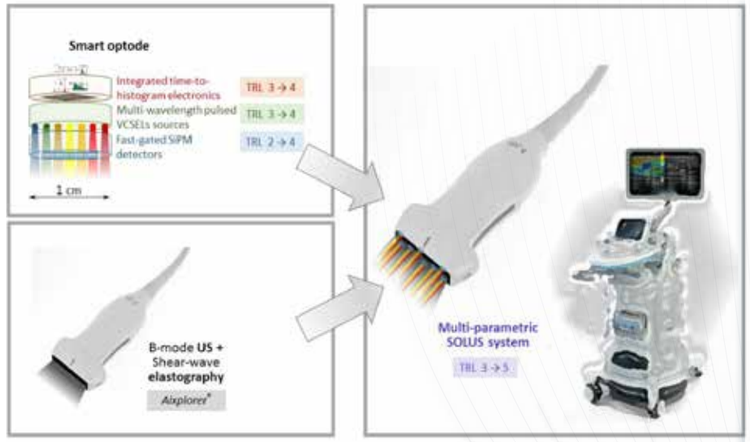
• CEA-Leti has developed the software, while other partners have finalized the hardware components and algorithms. **This software is a generic platform designed to facilitate re-use in similar projects** involving data acquisition, data processing and clinical study.

• CEA-Leti is also involved in analyzing and visualizing the data. **The integration of the optical tomography algorithms provided by the partner involved in their development has already started within the scope defined by CEA-Leti.**

• Finally, CEA-Leti has anticipated prototype usage during clinical tests. **The examination protocol and management of medical database have been jointly defined with the project radiologists.**

Objectives

SOLUS is a cross-disciplinary, 48-month project bringing together 9 partners: 4 industrials, academic and clinical institutions from 5 countries (engineers, physicists and radiologists) with cutting-edge expertise in their fields. The project involves developing an innovative non-invasive, point-of-care, low-cost, easy-to-operate, multi-modal imaging system (diffuse optics and ultrasounds/ shear wave elastography) for high-specificity diagnosis of breast cancer, which is the most common female cancer in Europe. Mammographic screening is effective in reducing mortality, however the 10-year cumulative false-positive risk is 50-60%, leading to unnecessary additional invasive procedures (e.g. biopsy). The project addresses the unmet clinical need for higher specificity in breast cancer imaging following screening by combining photonic with non-photonic techniques, developing and clinically validating innovative and previously unimagined photonic concepts and components. These include time-domain small source-detector distance featuring miniaturized picosecond pulsed laser sources and time-gated single-photon detectors for high dynamic range signal acquisition to achieve unprecedented sensitivity and depth penetration. For the first time, this allows comprehensive quantitative characterization of breast tissue including composition (water, lipids, collagen), functional blood parameters, morphologic information and mechanical parameters (stiffness). This innovative multi-parametric characterization will significantly improve the specificity of breast screening, will have a major impact on the quality of life of millions of European women and will offer huge savings for healthcare systems. Strong commitment of leading industrial players at all levels of the value chain will drive the European innovation process and make a significant contribution to ensure Europe's industrial leadership in the biophotonics healthcare market, while addressing one of the largest societal challenges in health and well-being.



The smart optode (new photonic device), the coupling with an ultrasound probe and the complete system.
© Solus

IMPACT

The project aims to improve the quality of life of women thanks to rapid, non-invasive diagnosis of breast cancer, while saving the cost of biopsies induced by erroneous positive screenings.

The device is a tool for monitoring tissue response to treatment, thereby making personalized therapy possible.

This collaborative work is intended to extend Europe's leadership in biophotonics with development of the smart optode, a sensor for time-resolved measurement in diffuse optics.

Publications

• «High throughput detection chain for time domain optical mammography», E. Ferocino, E. Martinenghi, A. Dalla Mora, A. Pifferi, R. Cubeddu, P. Taroni, Biomedical Optics Express 2018.

• «Instrumental, optical and geometrical parameters affecting time-gated diffuse optical measurements: a systematic study», A. Behera, L. Di Sieno, A. Pifferi, F. Martelli, A. Dalla Mora, Biomedical Optics Express 2018.

• «How should the new generation of detectors for diffuse optics be? A systematic simulation study», L. Di Sieno, A. Behera, A. Pifferi, F. Martelli, A. Dalla Mora, Biophotonics Congress 2018.

• «Chromophore decomposition in multispectral time-resolved diffuse optical tomography», J. Zouaoui, L. Di Sieno, L. Hervé, A. Pifferi, A. Farina, A. Dalla Mora, J. Derouard, J.-M. Dinten, Biomedical Optics Express 2017.

• «Non-invasive optical estimate of tissue composition to differentiate malignant from benign breast lesions: a pilot study», P. Taroni, A. M. Paganoni, F. Ieva, A. Pifferi, G. Quarto, F. Abbate, E. Cassano, R. Cubeddu, Scientific Reports 2017.

• «Attractive new technologies for 7-wavelength time domain optical mammography», E. Ferocino, E. Martinenghi, A. Dalla Mora, A. Pifferi, R. Cubeddu, P. Taroni, Diffuse Optical Spectroscopy and Imaging VI 2017.

• «Novel approaches to photon detection and timing for 7-wavelength time domain optical mammography», E. Ferocino, E. Martinenghi, A. Dalla Mora, A. Pifferi, R. Cubeddu, P. Taroni, Fotonica 2017.

• «Time-domain diffuse optical tomography using silicon photomultipliers: feasibility study», L. Di Sieno, J. Zouaoui, L. Hervé, A. Pifferi, A. Farina, E. Martinenghi, J. Derouard, J.-M. Dinten, A. Dalla Mora, Journal of Biomedical Optics 2016.

TRL
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Mathieu Perriollat
mathieu.perriollat@cea.fr



VIRUSCAN

Objectives

VIRUSCAN aims to apply cutting edge optomechanical developments to the biosensing and diagnostic fields and create a new interdisciplinary research community for advancing optomechanics, nanoelectromechanics, native mass spectrometry and biophysics towards clinical applications. VIRUSCAN will provide novel technology capable of identifying viral particles and assessing their infective potential through characterization of two physical parameters: mass and stiffness. Viral particle stiffness has been recently understood to act as a regulator of infectivity at different stages of the virus life cycle. Parallel advances in nanoelectromechanical systems have recently demonstrated that stiffness and mass information provided by nanoscale adsorbates can be extricated. Targeting intrinsic physical properties of viral particles will allow development of an open platform to tackle any virus and its mutations. VIRUSCAN will have an impact at all levels: providing personalized treatment to patients, reducing the use of ineffective antibiotics, increasing safety in blood transfusions, allowing quick, trustworthy response to emergency situations (e.g. EBOLA in West Africa and ZIKA in Brazil), curtailing the spread of viral infections and reducing costs per analysis and screening of a wide range of pathogens.

ViruScan

https://www.viruscanproject.eu/

Keywords
Biophysics
Microfluidics
Nanoelectromechanics
Optomechanics
Virology

Optomechanics for virology

Viral infections diagnosis demands novel, cheaper, rapid technologies to overcome today's constraints. The current gold standard for diagnosis of viral infections is based on pathogen-targeted nucleic acid identification, which cannot discern infectious stages from latent ones and demands time consuming adjustments, when mutations occur or new emerging viruses need to be included in diagnostic protocols. Recently, optomechanics has been implemented in fundamental developments in physics (gravitational wave detection, mechanical quantum ground states), but it has not yet delivered its full application potential.

CEA-Leti in VIRUSCAN

CEA-Leti is in charge of **developing a disposable sample preparation module based on passive microfluidics in order to isolate and concentrate virus particles** from a complex biofluid, such as plasma or serum, upstream to the nano-ESI and analysis chain. During the first 2 years of the VIRUSCAN project, **we have developed a first prototype** for the sample preparation module. Among the main achievements, we can highlight:

• **Development of a first fluidic cartridge ensuring** management of both fluidic and pneumatic circuits, and demonstration of a first set-up allowing progressive sorting of biological components (red blood cells and bacteria) from a complex biofluid using series-connected DLD modules

• **Design and fabrication of a set of DLD devices** with theoretical critical diameters suited to the viruses identified in the project. These DLD devices have been characterized with fluorescent polystyrene beads as a first model. We have evaluated their critical diameter and recovery rate. We have also tested the DLD devices with red blood cells as a biological particle model. Results are in close agreement with expected the performance characteristics for larger modules (up to structures with 5µm pillar diameter and inter-spacing gap, corresponding to a critical diameter of ~1µm). **A hydraulic resistance model has been developed for smaller modules** to optimize DLD geometrical parameters. **A new DLD set has been designed and is under fabrication** for this new module; it is designed to receive a higher flow rate and reduce sample processing time

• **Identification of a specific module for preparing the virus nebulization step, i.e. concentration of sorted viruses and option to contain them in an easy-to-nebulize solvent** (buffer exchange function). Among several exploratory designs, two have been selected and fabricated, and are being characterized.

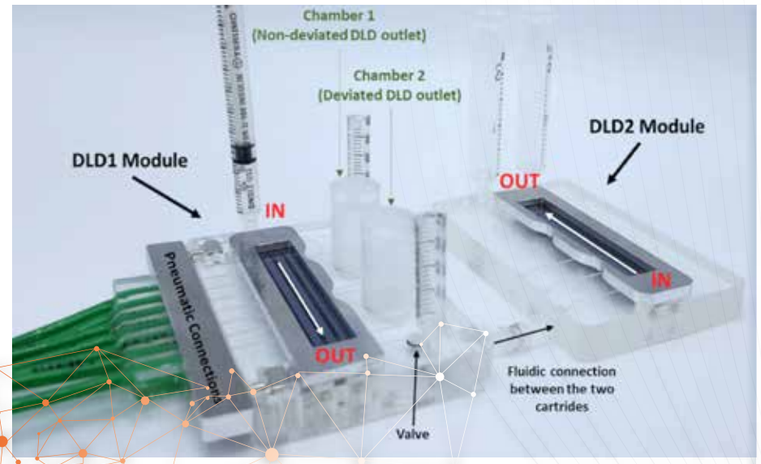


Illustration of the set-up used for the progressive sorting of particles in a complex media: serial connection between two DLD modules.
© CEA-Leti

IMPACT

This project is an opportunity for Europe to develop a new technology, namely a nanoscale fluidic sorting module, which requires a combination of skills and technical resources including silicon technology, biology, and microfluidics. Initial results are very encouraging, which has strengthened cross-fertilization between the partners and with the scientific community.

VIRUSCAN at a glance

60 months
Nov. 2016 > Oct. 2021

EC Programme
Call H2020 - FETPROACT-01-2016, Disruptive information technologies / Hybrid opto-electro-mechanical devices at the nanoscale

Project Coordinator
CSIC (SP)

Partners
DE: Heinrich Pette Institute - Leibniz Institute for Experimental Virology (HPI)
ES: Agencia Consejo Superior de Investigaciones Cientificas (CSIC), Servicio Madrileno de Salud (SERMAS)
FR: CEA-Leti, Université Paris Diderot (UPD)
GR: Fasmatech Science and Technology SA
NL: Nederlandse organistie voor toegepast natuurwetenschappelijk onderzoeck (TNO), Rijksuniversiteit Groningen (RUG)

Total budget
€ 7.14 m.

EC Contribution
€ 7.14 m.

Contract Number
731868

Publications

• *«Anticipating Cutoff Diameters in Deterministic Lateral Displacement (DLD) Microfluidic Devices for an Optimized Particle Separation», E. Pariset, C. Pudda, F. Boizot, N. Verplanck, J. Berthier, A. Thuaire, and V. Agache, Small, Volume 13, Issue 37, October 4, 2017.*
• *«Separation of Biological Particles in a Modular Platform of Cascaded Deterministic Lateral Displacement Modules», E. Pariset , C. Parent, Y. Fouillet, F. Boizot, N. Verplanck, F. Revol-Cavalier, A.Thuaire & V. Agache, Scientific Reports, 8:17762, 2018.*

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Aurélie Thuaire
aurelie.thuaire@cea.fr

METROLOGY & CHARACTERIZATION

3D Stack
3DAM
HADES
MADEin4
METRO4-3 D
NFFA - EUROPE
OBELICS
TSV HANDY

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3D Stack

Objectives

Outcomes of the More-than-Moore approach have included 3D objects on the micron scale, Through Silicon Via (TSV) and 3D heterogeneous integration. However, 3D characterization, metrology and inspection at micrometric-nanometric resolution and capacities of large-field analysis to inspect and measure groups of vias are needed along with control of wafer/chip thinning and bonding processes.

Existing state-of-the-art measuring methods suffer from lack of traceability, accuracy and quantification. The 3D Stack project focused on the traceability of existing instruments (optically based methods) by developing new standards and reducing uncertainty through new measurement protocols and methodologies. It developed new instrumentation (Scanning Probe Microscopy, Scanning Acoustic Microscopy and Synchrotron-based methods) to characterize TSVs before and after filling the bonding and thinning quality of wafers and dies.

This Joint Research Project's (JRP) objective was to develop metrological infrastructure and facilities for calibration standards and measurements of qualified material and cell devices.



http://empir.npl.co.uk/3dstack/

Keywords
3D-technologies
Characterization
Metrology
Trough Silicon Via (TSV)
Wafer Bonding

3D Stack at a glance

18 months
Jun. 2015 > Jun. 2018

EC Programme
EURAMET - EMPIR

Project Coordinator
Lne (FR)

Partners
BE: IMEC
CH: Metas
CZ: Cesky Metrologicky Institut
DE: Fraunhofer Izm, Physikalisch-Technische Bundesanstalt
FR: CEA-Leti, Fogale

Total budget
€ 1.4 m.

EC Contribution
€ 1.4 m.

Contract Number
Grant Agreement No. 14IND07
3D Stack

3D Stack - Metrology For Manufacturing 3D Stacked Integrated Circuits

One way of producing a complex component (object) is to stack parts of the component in three dimensions and to ensure an efficient interconnection path between the parts. The 3D Stack project involved establishing metrologies for assisting experts in diagnosing and improving successive process steps during component development.

CEA-Leti in 3D Stack

The 3D Stack project addressed the following scientific and technical objectives:

- Development of reliable 3D characterization and metrology methods for:
  - Cu-filled TSV samples and arrays with aspect ratios from 10 to 15
  - Wafers of various thicknesses and with different interconnection diameters before bonding and after CMP

- Development of methods to measure accurately electrical and thermal transport properties of nanostructured copper TSV interconnects

- Development of metrology tools, protocols and standards for high lateral and z resolution

- Characterization of post bonding overlay alignment on an available sample using IR microscopy, laser scanning IR and editing of a report on metrological assessment of IR microscopy and laser scanning IR limits in relation to post bonding overlay alignment suitable for micron size interconnects

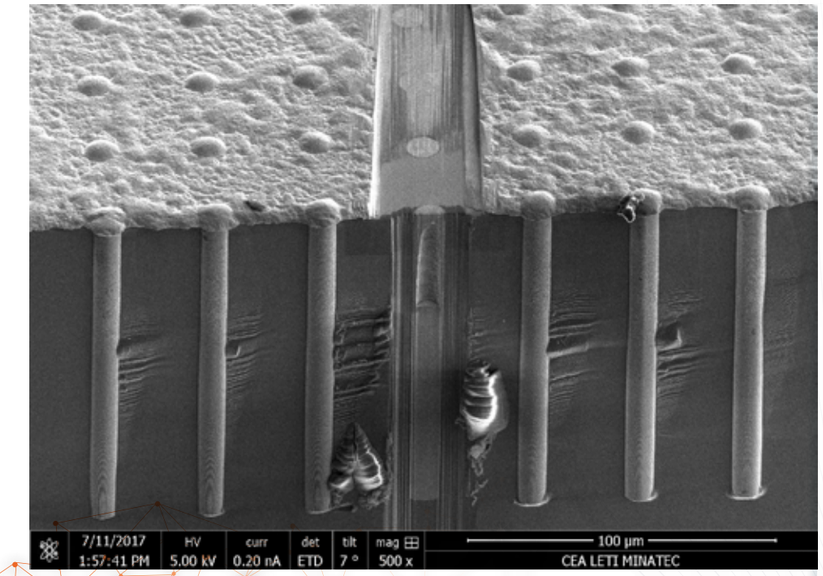
- Inspection of bonded/thinned wafers to characterize defect type (particle, voids, materials residue) and distribution during a bonding process

- On wafer/die bonding and thinning process aspects, dimensional characterization of samples and other properties (using confocal measurements, IR scan mode interferometry, confocal chromatic scan mode and spectral domain IR interferometry)

- Provision of traceable metrology for thickness uniformity control and surface quality of wafers/dies

- Based on other partner inputs, documented recommendation regarding the strategy for measuring TSV dimensional properties based on confocal microscopy, IR interferometry and optical microscopy traced to a metrological 3D Atomic Force Microscopy (AFM)

- Engagement with the semiconductor industry and other parties to facilitate technology take-up.



FIB SEM image of Cu-filled TSV preparation done at CEA-Leti for NMIs with void at top.
© CEA-Leti

IMPACT

The 3D Stack project had an immediate impact by providing European companies with traceable facilities for calibration standards and measurements of thermal and electrical material characterization, defect inspection for high-aspect ratio TSV and wafer/chip bonding and thinning processes through its ESIA trade association. Development of metrological tools and procedures contributed to transferring metrology solutions between R&D laboratories and fabrication centres, thereby extending cooperation and adding metrology to established techniques.

PTB is now offering the following nanodimensional calibration services: step height standards, depth-setting standards, 1D lateral standards, 2D lateral standards, 3D Nano standards and reference areal surface metrology. CMI have introduced a new calibration service based on 3D Stack project-developed methods, which offers local thermal measurement using a developed SThM system.

Publications

- *«What are the correct L-subshell photoionization cross sections for quantitative X-ray spectroscopy?», P. Hönicke, M. Kolbe, B. Beckhoff, X-ray spectrometry, 03-2016.*
- *«Investigating stress measurement capabilities of GHz scanning acoustic microscopy for 3D failure analysis», A. Khaled, S. Brand, M. Kogel, T. Appenroth, I. De Wolf, Microelectronics Reliability, 09-2016.*
- *«Development and characterization of sub-monolayer coatings as novel calibration samples for X-ray spectroscopy», P. Hönicke, M. Krämer, L. Lühl, K. Andrianov, B. Beckhoff, R. Dietsch, T. Holz, B. Kanngiesser, D. Weißbach, T. Wilhein, Spectrochimica Acta B, 04-2018.*
- *«Accurate experimental determination of Gallium K- and L3-shell XRF fundamental parameters», R. Unterumsberger, P. Hönicke, J. Colaux , C. Jeynes, M. Wansleben, M. Müller, B. Beckhoff, J. Anal. At. Spectrom / 05-2018.*
- *«Wafer Nano topography and Edge Roll-Off Metrology for 3D Monolithic Integration International», M. Abdel Sater, L. Brunet, N. Devanciard, V. Balan, C. Euvrard, Y. Exvrayart, C. Laborderie, C. Beitia, S. Godny, J.-F. Boulanger, S. Petitgrand, Y. Guillou, G. Fresquet, Unity, Imaps 2018 / 03-2018.*
- *«Atomic fundamental parameter determinations at PTB using well-known synchrotron radiation and calibrated instrumentation», B. Beckhoff, P. Hönicke, I. Holfelder, Y. Kayser, M. Kolbe, J. Lubeck, M. Müller, B. Pollakowski-Herrmann, R. Unterumsberger, J. Weser, Atomic fundamental parameter determinations at PTB using well-known synchrotron radiation and calibrated instrumentation / DXC 2018 / 08-2018.*
- *«Solutions to multiple probing challenges for test access to multi-die stacked integrated circuits», E. Marinissen, F. Fodor, A. Podpod, M. Stucchi, Y-R. Jian, C-W. Wu, IEEE International Test Conference / 10-2018.*

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Nicolas Devanciard
nicolas.devanciard@cea.fr

Narciso Gambacorti
narciso.gambacorti@cea.fr



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3DAM Titan Themis.

3DAM

Objectives

The aim of the 3DAM project was to develop a new generation of metrology and characterization tools and methodologies to allow development and introduction of upcoming semiconductor technology nodes. Based on Moore's law over the next decade, breakthrough developments are needed in lithography, device architectures and new materials. Nano-electronics technology is moving beyond the boundaries of (strained) silicon in planar or even finFETs, so new 3D device architectures and materials (e.g. nanowires, MX2 and 2D materials) are raising major metrology and characterization challenges, which cannot be met by pushing current methods to their limits.

http://ecsel.eu/web/projects/3DAM.php

Keywords
3D, Characterization
Instrumentation
Materials
Measurement
Metrology
Semiconductors

3DAM at a glance

36 months
Apr. 2016 > Mar. 2019

EC Programme
ECSEL JU

Project Coordinator
FEI Electron Optics B. V. (NL)

Partners
BE: IMEC
CH: ATT
DK: CAP, DTU
FR: AM-F, CAM, CEA-Leti, FEI-FR, STMicroelectronics
HU: Semil
IE: ADA
IL: AMIL, Bruker JV, Nova
NL: FEI, TNO, TU/e

Total budget
€ 13.87 m.

EC Contribution
€ 6.5 m.

Contract Number
692527

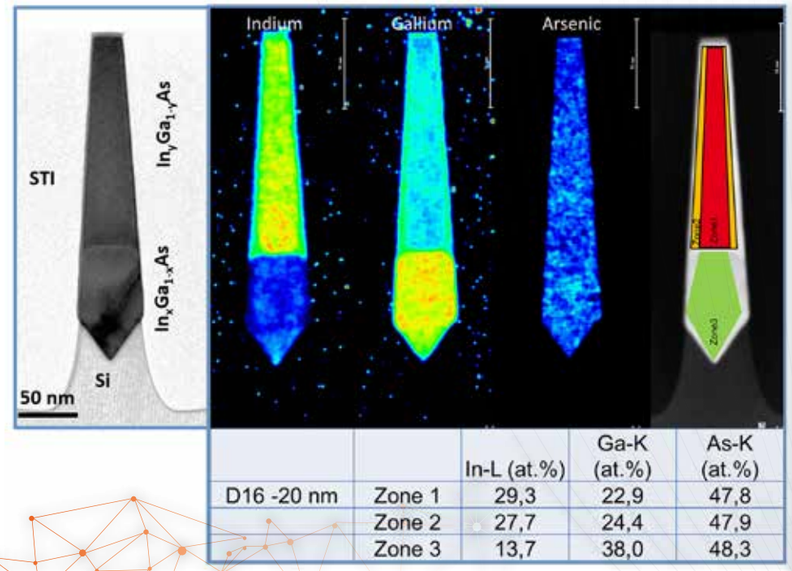
3D Advanced Metrology and materials for advanced devices

Continuous development of digital technologies has led to an abundance of semiconductor devices: tablets, smartphones, connected objects, cars, etc. To enhance the performance of such devices, the smallest dimension of their components, e.g. transistors, is currently much smaller than micrometer (0.000001 meter). Furthermore, silicon-based components now include materials such as Hafnium, Titanium, Germanium, etc. The aim of the European academic and industrial 3DAM project partners was to develop metrology and physical chemical characterization techniques or tools to measure and control future components, which will soon be just a few nanometers (0.000000001 meter) in size and will incorporate new materials with Gallium, Arsenic and 2D materials similar to graphene.

CEA-Leti in 3DAM

CEA-Leti's main contribution to 3DAM was delivering 300mm advanced technology node test wafers to the project partners and providing access to the nanocharacterization platform and its wide range of characterization techniques.

- Availability of the silicon technology platform providing test wafers for development of in-line methodologies (CD-SEM, 3D-AFM, OCD):
  - Front End of Line (FEOL): arrays of nanowires of different lengths and widths, stacked nanowires and nanowires inside dummy gates
  - Back End of Line (BEOL): TSV with 5 to 20µm top CD and medium-high aspect ratio.
- Cooperation with partners in developing complementary structural characterization techniques such as Electron Tomography in a TEM for FEOL qualification, X-ray tomography in a SEM for BEOL qualification, Cathodoluminescence (CL) and Photoluminescence (PL) techniques for defect characterization and identification, Nanobeam Electron Diffraction in a TEM and micro-RAMAN for strain analysis.
- Composition and doping measurements of SiGe and III-V materials using micro-RAMAN spectroscopy, TEM Energy Dispersive X-ray and Electron Energy Loss spectroscopies (EDX &EELS), low-impact-energy SIMS protocols and Atom Probe Tomography.
- Evaluation of PL and CL characterization for MX2 materials to extract information on thickness and crystal quality.
- Contribution to developing hybrid, correlative metrology, characterization protocols and workflows: study aim was to combine two or more complementary metrology or analytical methods for further improving overall control capabilities of technology development and ramp-up phases.
- Organization of a public workshop to disseminate the findings of the project at MINATEC Grenoble.



		In-L (at.%)	Ga-K (at.%)	As-K (at.%)
D16 -20 nm	Zone 1	29,3	22,9	47,8
	Zone 2	27,7	24,4	47,9
	Zone 3	13,7	38,0	48,3

STEM BF image of imec test sample: 50 nm fin of InGaAs.
© CEA-Leti

IMPACT

The metrology tool sets and characterization methods developed during the 3DAM project and their demonstrated 3D capabilities and performances are expected to prompt faster learning cycles and more efficient manufacturing and process control plans. In turn, this will lead to faster technology developments and ramp-up rates as well as steeper yield learning curves to ensure thereby shorter new product times to market and times to volume.

Publications

- *«Understanding and improving the low optical emission of InGaAs quantum wells grown on oxidized patterned (001) silicon substrate», J. Roque et al., Applied Physics Letter, April 2018.*
- *«Comprehension of peculiar local emission behavior of InGaAs quantum well by colocalized nanocharacterization combining cathodoluminescence and electron microscopy techniques», J. Roque et al., Journal of Vacuum Science & Technology B, April 2018.*
- *«2D & 3D advanced Transmission Electron Microscopy for semiconductor characterization», V. Delaye, Workshop in the frame of the EU projects 3DAM and Metro4-3D, 20-April 2018, IMEC, Belgium (Leuven).*
- *«2D & 3D advanced analytical STEM studies for MOSFETs dopant characterization», V. Delaye, Z. Saghi, JEELS 2018: 11èm Journées d'EELS, June 2018.*
- *«Advanced STEM-EELS for Nanotechnology and renewable energy research and development», V. Delaye, N. Bernier, Z. Saghi., EDGE 2017 Conference, 14-19th May 2017 Japan.*
- *«Developments on a SEM-based X-ray tomography system: stabilization scheme and performance evaluation», L.A. Gomes Perini et al., Review of Scientific Instruments, June 2017.*

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Vincent Delaye
vincent.delaye@cea.fr

Narciso Gambacorti
narciso.gambacorti@cea.fr



HADES

http://www.penta-eureka.eu/downloads/ProjectProfiles/penta-project-profile-16003-hades.PDF

Keywords
Analogue to digital convertor, Analogue mixed signal, Application-Specific integrated circuit, Automatic test equipment, Built in self-test, Design for security, Design for testability, Embedded test instrument, Hierarchical on-line testing, Inter-integrated circuit interface, Internal JTAG, Joint Test Action Group (JTAG), Key performance indicator, Logical built in self-test, Memory BIST, Original equipment manufacturer, Process Control Monitor (PCM), Physical Failure Analysis (PFA)

HADES at a glance

36 months
Apr. 2017> Apr. 2020

EC Programme
PENTA

Project Coordinator
STMicroelectronics (FR)

Partners
FR: CEA-Leti, CNRS, Institut Supérieur Social de Mulhouse, IROC TECHNOLOGIES, Laboratoire d'Informatique de Robotique et de Microélectronique de Montpeller, NXP Semiconductors France, Sorbonne University – LIP6, STMicroelectronics,TEMENTO SYSTEMS, Thales, TIMA
NL: D4T Systems, JTAG Technologies B.V., NXP Semiconductor Netherlands BV, University of Twente

Total budget
€ 14.6 m.

EC Contribution
€ 0.3 m.

Contract Number
777053

Hierarchy-Aware and secure embedded test infrastructure for Dependability and performance Enhancement of integrated Systems

The HADES project is demonstrating the benefits of using testing tools embedded in complex systems to reduce cost and enhance dependability.

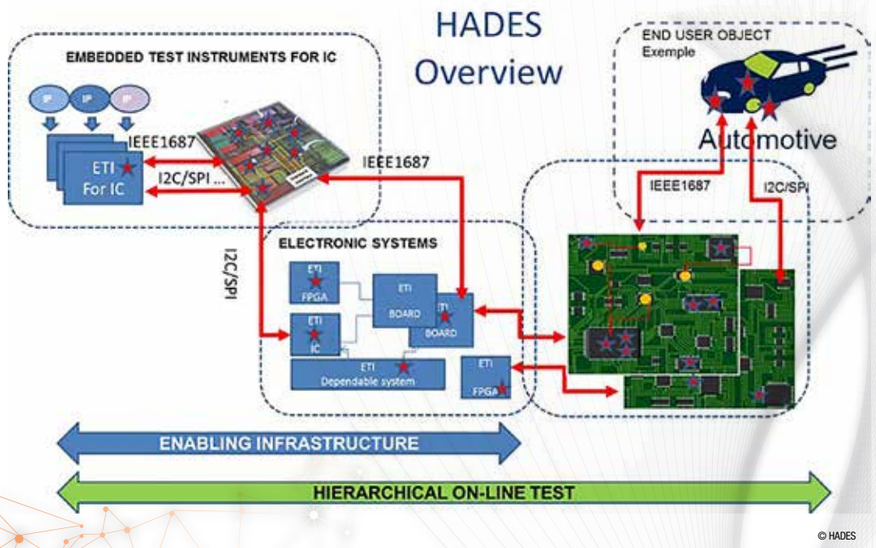
CEA-Leti in HADES

CEA-Leti is working on an embedded test for RF and mm-wave building blocks. Development of RF and mmW BIST solutions has great potential to overcome conventional testing issues. Signal handling would remain internal, thus eliminating conveyance problems and one of the objectives is to simplify or avoid generation of RF tones. Dedicated RF tone generators, usually based on RF VCOs, offer high RF performance but at the cost of design complexity and considerable overhead area. Moreover, analysis of substrate coupling at mmW frequencies is a key issue in ensuring a test. However, design methodology with a coupling extraction tool at silicon level will avoid testing issues due to inter-block coupling.

Simplifying test stimulus generators, reusing existing resources for up-conversion of baseband stimuli and eliminating RF stimuli are research paths worth pursuing in this connection.

Objectives

The HADES project aim is to provide a hierarchy-aware, smart and secure, embedded testing infrastructure for the enhancing dependability and performance of integrated systems. To achieve this ambition goal, HADES is advancing from the conventional design and post-silicon fabrication testing approach to a new, cheap and efficient, scalable on-line paradigm. More specifically, the project is targeting markets featuring: i) machine-to-machine and connected systems, ii) remote-controlled systems, iii) smart home and mobile phone systems, iv) safety-critical systems typically encountered in automotive and avionics fields, v) mission-critical, including space-based, systems and security applications. HADES outcomes are prompting added value at system and user levels through secure testing infrastructure (ETIs and associated tools) used for hierarchical on-line tests specified in the relevant application field. The HADES project is intended to support multiple industrial applications based on standards IEEE JTAG1687 for large digital SoCs and SPI or I2C for smaller digital SoCs or for RF/Analog blocks in mixed-signal SoCs. On project completion, HADES will provide electronic components and subsystems and IoT systems with: i) test capabilities and reusability throughout a product life cycle, ii) test bus access at required security level, iii) test costs compatible with IoT low-cost devices and high volume, iv) on-line monitoring for enhanced dependability, prognosis and diagnosis and, v) on-line monitoring for system-level power management. The project is providing system manufacturers with greater robustness and dependability as well as a key competitive advantages for European industry. Like the ancient Greek god Hades (who wore a cap of invisibility when entering the higher world), the hierarchical embedded test infrastructure developed within the scope of the HADES project is transparent to the monitored system.

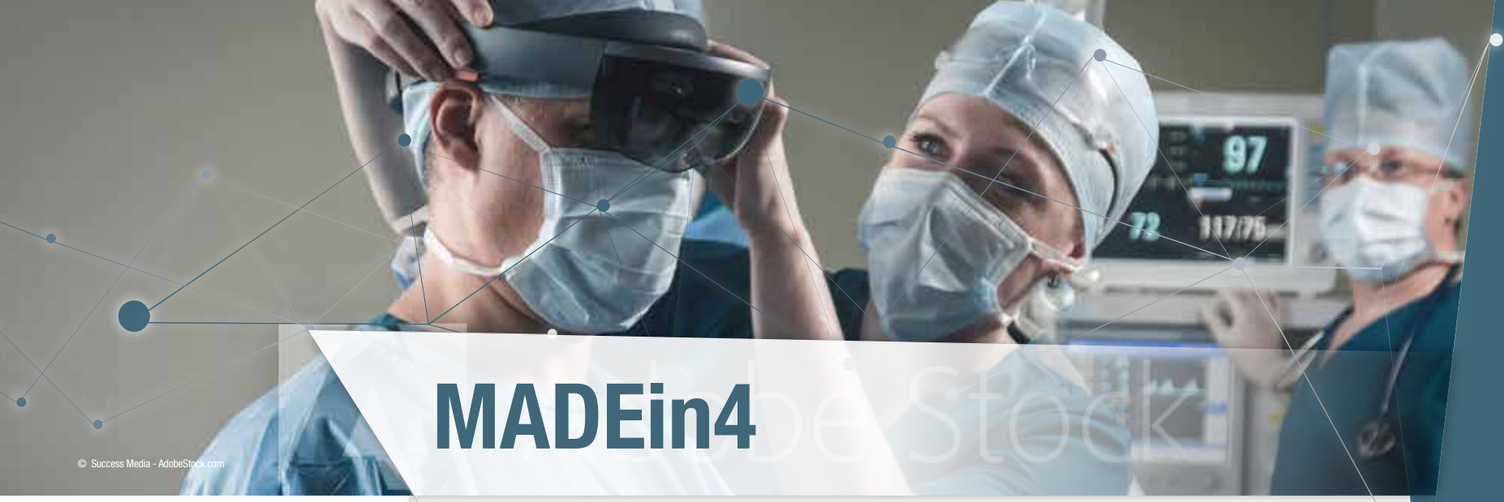


IMPACT

HADES project innovations will offer the consortium the option of commercializing safer and more robust ICs, devices or final equipment and market access will be reinforced by the competitive advantages generated by HADES. System reliability and dependability are key differentiators with regard to competition and the project will ensure both a larger market share and competitiveness, mainly in critical and safety systems, to maintain Europe's leadership and employment.

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Emeric Defoucauld
emeric.defoucauld@cea.fr



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MADEin4

MADEin4

Keywords
Automotive, Digitization Equipment, HPC Inspection, Manufacturing Metrology, Pilot line Platform Predictive yield, Process Semiconductor

MADEin4 at a glance

36 months
Apr. 2019 > Mar. 2022

EC Programme
H2020-ECSEL-2018

Project Coordinator
Applied Materials Israël (AMIL)

Partners
AUS: AVL, AVL DiTEST, VIF
BE: ICOS, IMEC
DE: Intergrated Circuit Testing GmbH, PTB, PVA Tepla Analytical Systems, Semi Europe, Thermo Fischer Scientific
FR: Aix-Marseille University, Arkema, CEA, CNRS, Entegris Cleaning Process, IMT, Ippon Innovation, Mentor Graphics, Octo Technology, Pfeiffer Vacuum SAS, STMicroelectronics, Unity Semiconductors
HU: Semilab
IL: Applied Materials, Brillianetolsr, Bruker JV, KLA-Tencor Israël, Mellanox, Nanomotion, Nova Measuring Instrument Ltd, Tower Semiconductor
IT: CNR, Comau, FCA Italy, POLITO, STMicroelectronics
NL: Nearfield Instruments BV, OKO Tech, Prodrive, Thermo, TNO, TU-Delft, TU-Eindhoven
RO: University Politechnica Bucharest
SE: Excillum AB

Total budget
€ 12.8 m.

EC Contribution
€ 4.8 m.

Contract Number
Grant Agreement No. 826589

Metrology Advances for Digitized Industry 4.0

The aim of the MADEin4 project was to boost the productivity of the main high-tech sectors embracing automotive and electronic component and system production. Better control of each process step was ensured by implementing new metrology tools and efficient, cutting-edge computing solutions. A pilot production line demonstrated the project outcome.

CEA-Leti in MADEin4

CEA-Leti's prime outcome from the MADEin4 project was highlighting its technological capabilities in terms of fabricating cutting-edge samples in the field of patterning and photonics. This is essential to optimizing novel, integrated metrology and process control solutions for the next generation of technological platforms. CEA-Leti contributed to MADEin4's main technical worksheets, the most important of which addressed metrology platform developments. Moreover, the Institute played a key role in assembling the principal results of 47 project partners in strategic metrology fields such as contamination control, X-ray analysis, advanced packaging and CD measurements.

Objectives

MADEin4 addressed metrology as a key enabler of productivity enhancement in many industries across the electronic components and systems value chain. Its main ambition was to raise the level of productivity and predictability of component production lines in the electronics and automotive industries, while fulfilling or even exceeding sensitivity, precision and accuracy requirements. In demonstrating the «industry 4.0» concept, MADEin4 brought together, for the first time, all the metrology and data management industrial players by closely cooperating with key semiconductor and automotive industries, European RTOs and relevant academic teams. The global, direct objectives of the MADEin4 project were to:

- Develop high through-put, next generation metrology and inspection tools usable down to the 5nm node on behalf of the nanoelectronics industry
- Develop cyber physical systems integrating machine learning of design and metrology data on the production line, enabling very high sampling and data rates and, ultimately, predictive diagnostics of the production process
- Demonstrate the «industry 4.0» concept on a pilot production line.


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IMPACT

The primary anticipated impact of MADEin4 is a significant increase in market share for Europe's metrology companies followed by improvements at Europe's major semiconductor manufacturing and packaging facilities, automotive manufacturing operations and ownership costs. Ultimately, MADEin4 will enable Europe to rank with the best in the world based on the novel manufacturing solutions implemented in the project.

Publications
The MADEin4 project just started in April 2019 therefore no communication/publication is available yet.

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Olivier Renault
olivier.renault@cea.fr

Yannick Le Tiec
yannick.letiec@cea.fr



METRO4-3D

Objectives

A driver of semiconductor industry growth is sustained compliance with “Moore’s Law”, whereby the number of transistors in an integrated circuit doubles approximately every two years along with an associated increase in circuit functionality, reduction in operational power and, most importantly, reduction in unit cost. These rapid technological developments, which embrace increasing process and material complexity and lower tolerance levels for process excursions, have increased the need for a more controlled manufacturing environment requiring equivalent improvements and developments in metrology. Today’s evolution towards merging of Lab-to-Fab metrology means that these developments are necessary at both R&D and final production stages.
Multiple material issues and phenomena depend strongly on size so metrology has to be increasingly performed on devices of realistic dimensions and on the wafer scale.
The METRO4-3D project assessed three metrology tools:
• A TOFSIMS system (ION-TOF) with built-in Scanning Probe stage and FIB column for true 3D-composition profiling in confined and structured failure analysis devices
• A fully automated microHall and sheet resistance measurement tool (CAPRES) addressing similar structures but sampling their electrical properties and featuring additional capabilities for measurements on dedicated test structures (prior to full BEOL)
• A GHz scanning acoustic microscope (PVA TePla) with a frequency range of up to 2 GHz (PVA TePla) for probing various defects in BEOL layers such as cracks, delamination, defectivities (e.g. voids), through Si vias (TSVs) and micro-bumps, as well as voids or cracks in stacked dies and wafers. This instrument was correlated to contamination (=composition) in specific areas probed with the TOFSIMS/FIB concept.

Metrology for future 3D-technologies

The METRO4-3D project assessed the suitability of three metrology tools able to measure composition, structural defects and electrical properties and thereby address the manufacturing challenges associated with 3D devices, which range from probing basic layer properties at device level to checking connections between chips for voids.

http://www.metro4-3d.eu/

Keywords
3D structure for microelectronics, Automated micro-Hall and sheet resistance measurement tool, Copper interconnects, FinFETS, GigaHertz acoustic microscopy, Scanning probe microscopy (SPM), Time-of-fllght secondary ion spectrometry (TOF-SIMS), X-ray tomography

METRO4-3D at a glance

36 months
Jan. 2016 > Feb. 2019

EC Programme
H2020-ICT-2015

Project Coordinator
IMEC (Be)

Partners
AT: Materials Center Leoben Forschung GMBH
BE: Lam Research Belgium
CH: Eidgenossische Materialprufungs- und Forschungsanstalt
DE: Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V., Ion-Tof Technologies GMBH, PVA Tepla Analytical Systems GMBH,
DK: Capres AS, Danmarks Tekniske Universitet
FR: CEA-Leti

Total budget
€ 3.3 m.

EC Contribution
€ 2.7 m.

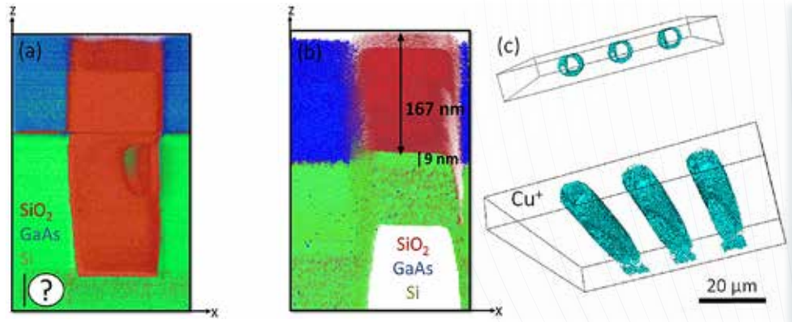
Contract Number
688225

CEA-Leti in METRO4-3D

CEA-Leti acquired a succession of 2-dimensional chemical images by depth profiling using dual beam time-of-flight secondary ion mass spectrometry (ToF-SIMS). These images could be used to generate a 3-dimensional (3D) visualization of the sputtered volume. However, standard reconstruction methods do not take into account the initial sample topography or lateral variations in sputter rates: the resulting 3D chemical visualization may be distorted in heterogeneous, nonplanar samples. ToF-SIMS analysis was combined with Atomic Force Microscopy (AFM) to address this issue. This correlation provided the missing sample topography and allowed sputter rates to be calculated. The protocol for accurate 3D ToF-SIMS reconstruction comprised AFM topographical images, crater depth measurements and sequences of ToF-SIMS images, all acquired for the same sample area. A 3D overlay between the AFM and ToF-SIMS images at each interface could thereby be created. Furthermore, the morphological information could be used to map the local sputter rate.

CEA-Leti developed accurate data processing for correcting the 3D ToF-SIMS reconstruction within the rendered volume defined by successive AFM imaging. This work was presented at the AVS 65th International exhibition and symposium by Maiglid Moreno, who received first prize in the Applied Surface Science Division.

The project also allowed us to evaluate a combined SPM TOF-SIMS and compare it with ex-situ approaches developed at CEA-Leti. Evaluation of advanced data treatment algorithms for improving image resolution and signal-to-noise ratio was also undertaken.



(a) Uncorrected 3-D TOF-SIMS volume;
(b) corrected 3-D TOF-SIMS volume using topography from AFM;
(c) 3-D FIB-TOF-SIMS reconstruction of a TSV showing a void at the top.
© CEA-Leti

IMPACT

Open access to instruments and publicity through conferences during the METRO4-3D project led to the rapid adoption of the three instruments assessed during the project, which is of benefit to the European companies that develop these instruments. A good synergy between partners led to mutual improvement of experimental methodology (including novel correlative metrology approaches) as well as dissemination of advanced data treatment algorithms.

Publications

• *«Combined ToF-SIMS and AFM protocol for accurate 3D chemical analysis and data visualization», M.-A. Moreno, I. Mouton, N. Chevalier, J.-P. Barnes, F. Bassani, B. Gautier, Journal of Vacuum Science & Technology B 36(3):03F122, 2018.*
• *«Combining TOF-SIMS with X-ray nanotomography or AFM : fusion of morphological and hyperspectral datasets for nanoelectronic and energy applications», DOI: 10.1116/1.5019464, J.-P. Barnes, A. Priebe, G. Goret, G. Audoit, M.-A. Moreno Villavicencio, I. Mouton, N. Chevalier, J. Laurencin, A. Bordes, E. De Vito, P. Bleuet, B. Gautier. Invited talk 21st International SIMS conference, Krakow, Poland, 10-15 septembre 2017.*
• *“Combined ToF-SIMS and AFM Protocol for Accurate 3D Chemical Analysis and Data Visualization”, M.-A. Moreno, N. Chevalier, J.-P. Barnes, I. Mouton, F. Bassani, B. Gautier, AVS 65, Long Beach, CA, USA, 22-26 octobre 2018.*

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Jean-Paul Barnes
jean-paul.barnes@cea.fr

Narciso Gambacorti
narciso.gambacorti@cea.fr



NFFA - EUROPE

Objectives

The underlying objective of the NFFA project was to implement integrated, distributed research infrastructure as a platform supporting comprehensive user projects in multidisciplinary nanoscale research. Project content ranges from synthesis and nanolithography to nanocharacterization, theoretical modelling and numerical simulation through coordinated open access to complementary research facilities. Integration and extension of existing specialized infrastructure capacities within a prime knowledge and know-how network enabled many multidisciplinary researchers to make advanced proposals impacting science and innovation. The NFFA-EUROPE project's full suite of key infrastructures was made accessible to a broader community of research players operating at different levels of the value chain. This included SMEs and applied research facilities that currently lack the benefits of these enabling technologies.

Nanoscience Foundries and Fine Analysis - Europe

Designed to enhance European competitiveness in nanoscience research and innovation, the NFFA project integrated the capabilities and laboratories of 20 EU partners by providing access for European scholars and engineers to state-of-the-art instruments, protocols and methods.

www.nffa.eu

Keywords
Infrastructures
Nanofabrication
Nanoanalysis
Simulation

NFFA - EUROPE at a glance

60 months
Sep.2015 > Sep. 2020

EC Programme
H2020-INFRAIA-1-2014-2015

Project Coordinator
CNR-IOM (IT)

Partners
CH: Ecole Polytechnique Federale de Lausanne, Paul Scherrer Institute
DE: Forschungszentrum Juelich GmbH, Karlsruhe Institut fur Technologie, Stiftung Deutsches Elektronen-Synchrotron Desy, Technische Universitat Munchen
EL: Foundation for Research and Technology - Hellas
EU: Installation Européenne de Rayonnement Synchrotron
FR: CEA, CNRS
IT: Consiglio Nazionale delle Ricerche, Promoscience s.r.l., Università degli Studi di Milano
SE: Lunds Universitet

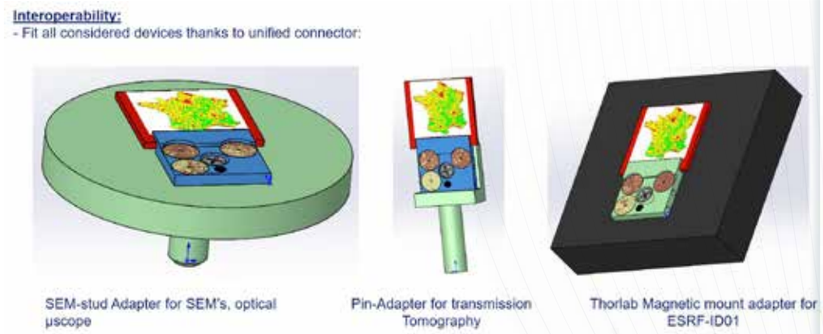
Total budget
€ 11,7 m.

EC Contribution
€ 10 m.

Contract Number
654360

CEA-Leti in NFFA - EUROPE

CEA-Leti worked with partners CNRS, DESY, ESRF, FORTH and JULICH to develop advanced nano-object transfer and positioning. The aim was to address integration of laboratory and large scale facilities to enable structural, chemical, magnetic or electronic analysis in 1) identical nanoscale sample areas, 2) implementing several complementary detailed analysis and large scale facility techniques and 3) various relevant applications and industrial environments. The project focused on allowing users from a wide range of scientific fields to conduct novel nanoscience based on a one-to-one structure-property relationship of single nano-objects or nano-assemblies. **The NFFA project drew up standard protocols to provide new capabilities for the user wishing to analyse the same nano-object using different hardware located at various research centres.** For example, this provided CEA-Leti with a methodology and the necessary hardware to analyse nano-objects in the same nano-location using different equipment, e.g. DB-FIB, P-FIB, SEM, AFM, etc. The project offered an excellent opportunity to strengthen our relations with different research institutes across Europe. CEA-Leti contributed to nano-characterization infrastructure with the other 11 partners to offer integrated access to advanced characterization of nanosystems grown and/or nanofabricated at other project facilities. This also allowed collected experimental data to be simulated or interpreted in conjunction with the conceptual facility. Each facility offered a unique combination of laboratory-based methods (e.g. atomic resolution imaging, electron transport measurement, optical magnetometry or XPS and synchrotron X-ray or neutron beamlines for scattering and spectroscopy, ultrashort pulse table-top and prospective FEL beamlines). Within this international framework, **CEA-Leti provided access to TEM, SEM, DB-FIB, P-FIB, Nano-AES, CL, PL, AFM, APT, XCT, XRD/XRF, Raman, ToF-SIMS, XPS and PEEM.**



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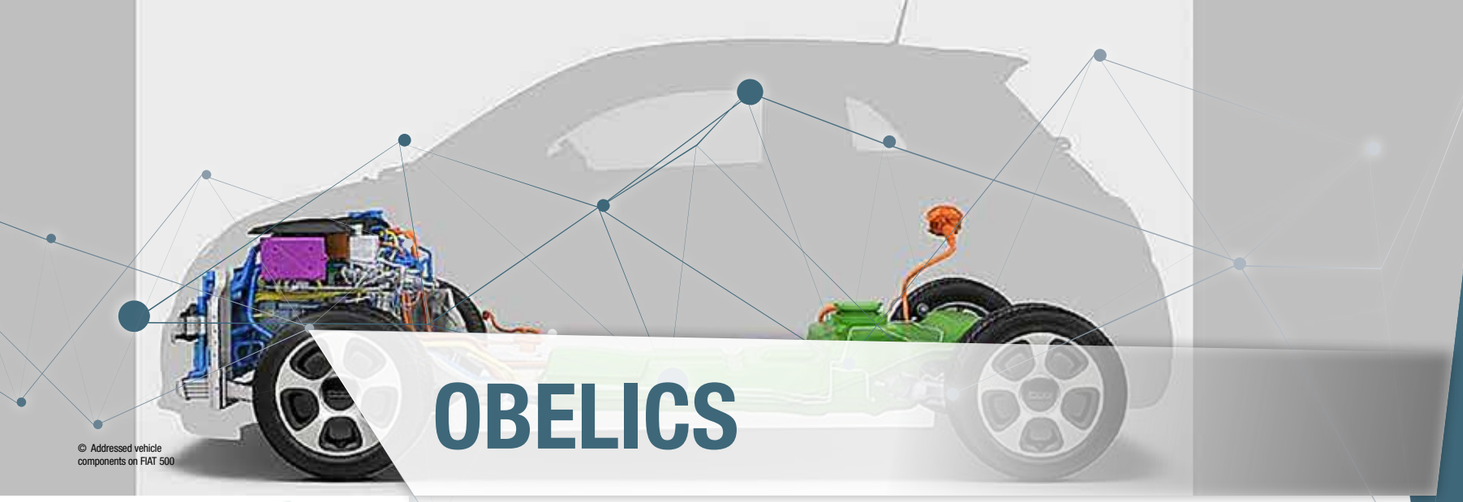
It is reckoned that about 1000 external users benefitted from NFFA-EUROPE during the project life. Scientist and industrial engineers from across Europe enhanced their research programs using complementary methods, measurements or calculations. The NFFA project allowed CEA-Leti to extend its visibility especially in relation to its material and device analysis capabilities by providing user access to its state-of-the-art nanocharacterization platform.

Publications

• *«Magnetoelectric dual-particulate composites with wasp-waisted magnetic response for broadband energy harvesting», P. Galizia, M. Alguero, N. Bernier, N. Gambacorti, E. Aza, A. Lappas, M. Venet, C. Galassi Journal of Alloys and Compounds, 783 (2019) 237-245.*

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Narciso Gambacorti
narciso.gambacorti@cea.fr



© Addressed vehicle components on FIAT 500

OBELICS

Optimization of scalaBle rEaltime modeLs and functIonal testing for e-drive ConceptS

The OBELICS project addresses the urgent need for new tools for multi-level modelling and testing of EV and their components to deliver more efficient vehicle designs faster, while supporting modularity to enable mass production and hence greater affordability through production cost reduction.

https://obelics.eu/

Keywords
Battery
Cell model
Drive train
Electric vehicle simulation
Impedance spectroscopy
Reliable modelling approach
Safety
System scalability

OBELICS at a glance

36 months
Oct. 2017 > Sep. 2020

EC Programme
H2020-EU.3.4

Project Coordinator
AVL List GMBH (AT)

Partners
AT: AVL List GMBH, FH Joanneum Gesellschaft, Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft mbH (Vitual Vehicle)
BE: Vrije Universiteit Brussel, Siemens Industry Software NV
DE: AVL Software and Functions GmbH, Bosch GmbH, Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung E.V.(FhG-LMB)
FR: CEA, Siemens Industry Software SAS, Valeo Equipements Electriques Moteur SAS, Renault Trucks SAS
GB: University of Surrey
IT: Universita degli Studi di Firenze, Centro Ricerche Fiat SCPA (CRF)
NL: Uniresearch BV
SI: Univerza V Ljubljani
TR: Ford Otomotiv Sanayi Anonim Sirketi

Total budget
€ 9.1 m.

EC Contribution
€ 9.1 m.

Contract Number
Grant agreement ID: 769506

Objectives

The impact of global warming is becoming increasingly clear and the environmental impact of conventional fossil-fueled vehicles is now under the close scrutiny of both the authorities and the public. Electric vehicles and electrified transportation are emerging as the only sustainable alternative to preserving the environment and guaranteeing the mobility needs of the future. Although the switch from conventional to EV represents a major challenge for the automotive industry, with significant obstacles still to be overcome, it also represents a major market and employment opportunity for the entire supply chain. Before mass deployment of EVs can become a reality, it is crucial to guarantee that their real operational performance, safety, reliability, durability and affordability is at least comparable to those conventional vehicles. Today's state-of-the-art EVs do not reach these targets because of the limited technical maturity of key components (e.g. batteries) and insufficiently available know-how and tools in all areas including testing and simulation. Today, industrial R&D must focus on bringing new, improved mass-production compliant vehicles to the market rapidly, implementing advanced components and architectures for higher operational efficiency. In this context, the OBELICS project addresses the urgent need for new tools to allow multi-level modelling and testing of EVs and their components to deliver more efficient vehicle designs faster, while supporting modularity to enable mass production and hence greater affordability. OBELICS is targeting a step change in performance (+20%, i.e. from 100 Wh/kg to 120 Wh/kg), efficiency (+20%), safety (+ factor of 10) and service life (+30%, i.e. from 100,000 km/8 years to 130,000 km years/11 years) of e-drivetrains and development time (- 40%, i.e. from 5 years to 3 years) and efforts (-50%, i.e. from 100 fte and 30 M€ to 50 fte and 15 M€).

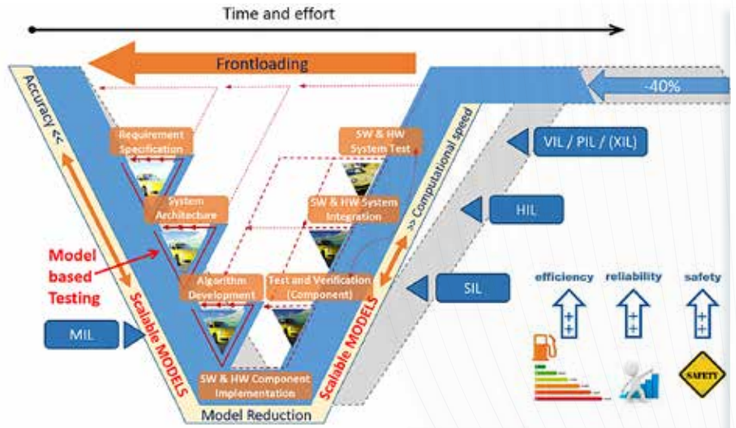
CEA-Leti in OBELICS

CEA-Liten and CEA-Leti have established close cooperation in the OBELICS project to fulfill the following project tasks:

• CEA-Liten: development of innovative, enhanced mathematical and electrical models for motor and battery-cell representation and simulation; development and testing of a dedicated embedded system (MCU-based) capable of measuring the electrochemical impedance of a Li-ion cell under active excitation and independently of the vehicle inverter.

• CEA-Leti: ensuring that algorithms at the basis of cell excitation and impedance measurement are adjusted to the selected cell; provided more algorithms to exploit the impedance measurement and the assumptions to be taken from the cell model for development of a new approach to battery safety assessment by exploiting the most meaningful parameters.
From broader standpoint, OBELICS is developing innovative, reliable modelling approaches based on first principles (using mechanistic, physical, electrochemical, electro-thermal and electromagnetic models), which are real-time capable and allow for the systematic scalability towards real-time models that are developed within the project scope. The project ensures model compatibility of different components and development levels-phases.

The underlying concept of OBELICS is to implement systematic modelling and testing (and corresponding corrections) of a system from the initial phase onwards. In traditional design flows, there can be no systematic testing of the entire system until it has been fully implemented. Design problems therefore remain hidden until late in the system development, at which point their remediation is significantly more costly and disruptive. Shifting to model-based testing, as envisioned within OBELICS, enables engineering teams to understand more readily design change impacts, communicate design intent and analyze a system design before it is built.



OBELICS model based development concept to reduce development and testing efforts.
© Obelics



IMPACT

The overall aim of the OBELICS project is to develop a systematic and comprehensive framework for the design, development and testing of advanced e-powertrains and EV line-ups. This will curtail development efforts by 40%, while improving efficiency of the e-drivetrain by 20% and increasing safety by a factor of 10, using OBELICS' advanced heterogeneous model-based testing methods and tools along with scalable, easy-to-parameterize, real-time models.

Publications

• *«Electronic module for the thermal monitoring of a Li-ion battery cell through the electrochemical impedance estimation», M. Ranieri, et al., Microelectronics Reliability, Volume 79, December 2017, Pages 410-415.*
• *«Tracking of electrochemical impedance of batteries», H. Piret, P. Granjon, N. Guillet, 2016, Journal of Power Sources,Volume 312, 30 April 2016, Pages 60-69.*

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Marco Ranieri
marco.ranieri@cea.fr

Bernard Strée
bernard.stree@cea.fr



TSV HANDY

TSV-HANDY

http://www.catrene.org/web/downloads/profiles_catrene/catrene-project-profile-TSV-Handy.pdf

Keywords
3D
Handling
Integration
Sorter
Thin wafer

TSV HANDY at a glance

36 months
Apr. 2015 > Mar. 2018

EC Programme
CATRENE, call 7 (2014)

Project Coordinator
RECIF (FR)

Partners
AU: Evg
BE: Imec
DE: Entegris
FR: CEA-Leti, Fogale, Recif, ST Microelectronics
PO: Nanium

Total budget
€ 1.8 m.

EC Contribution
€ 0.7 m.

Contract Number
152930105 EJN° 2101747881

Hvm AND Yield optimisation

The aim of the TSV HANDY project was to contribute to improving output in manufacturing silicon-based products through development of an innovative handling system.

Objectives

Through Silicon Via (TSV) is a “More-than-Moore” technology that allows development of new chip architectures. A number of challenges remain in the several process steps for making TSV products cost efficient. The project aimed to provide HVM ramp-up support and improvement in TSV product manufacturing yield.

Challenges addressed in the project:
- Handling of 300 mm heterogeneous wafers with edge trim inspection
- Development of metrology and new logistical concepts for wafers on 380mm frames
- Improvement of temporary bonding and debonding processes.

Synergies were created with other CATRENE projects such as NGC450, SOI450 and MASTER_3D.

The project plan was broken down into four work packages extending over 3 years.

The industrial partners released new products to the market in 2018.

CEA-Leti in TSV HANDY

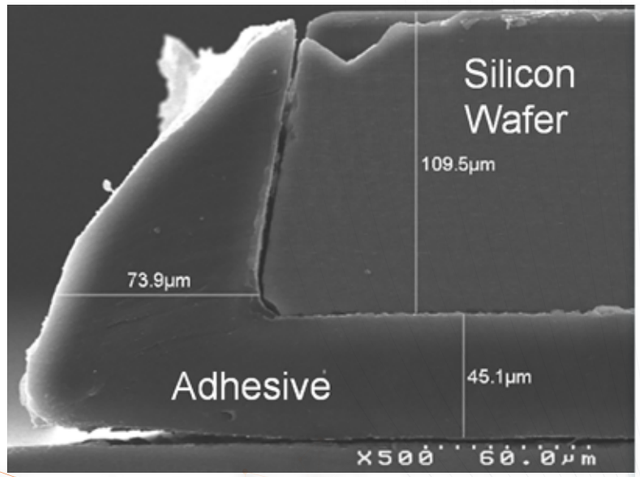
CEA-Leti activity:

- The main task of the year was to modify the current 300 mm EVG560 bonder used at CEA-Leti. Performed at EVG headquarters, this involved adding a coating capability to the existing tool. EVG delivered the coater tool to CEA-Leti in August 2016. The bonding and coating capabilities of the new tool were validated with a polymer adhesive. The quality of the bonding process were excellent and the resulting bonded stack exhibited no defect (void or de-lamination). This created a robust process suitable for production. The operational coating produced an adhesive film with no air bubbles or de-wetting areas and the bonding process obtained from this structure was defect-free.

- A project sub-task was to select an efficient temporary adhesive for use in the new EVG560 tool. For this, a vehicle test was defined and CEA-Leti identified a polymer adhesive compatible with high temperature processes. We demonstrated that a bonded structure using the new adhesive did not exhibit de-lamination below 350°C, whereas a standard adhesive de-laminated from 250°C. This compound is thus very promising in particular for high temperature oxide deposition.

- A study of the de-bonding process was started and CEA-Leti demonstrated the possibility of on-frame de-bonding of the new adhesive, leading to a dismounted wafer with no cracking or chipping.

- CEA-Leti is now in a position to supply various 300 mm 3D wafers to RECIF and FOGALE for designing and testing a the new inspection tool.



Cross section of a 3D wafer manufactured at CEA-Leti.
© CEA-Leti

IMPACT

The TSV HANDY project prompted strong collaboration between CEA-Leti and EVG. It entailed setting up a new coating capability on existing equipment in the CEA-Leti clean room.

The project also promoted CEA-Leti as a European leader in the field of 3D integration: we supplied various 3D wafers for upgrading the inspection tool at RECIF and FOGALE.

The TSV HANDY project has led to delivery of an automatic platform for inspecting and handling 3D wafers. To our knowledge, it is the first time that such a tool has been developed and installed in AMKOR in an industrial environment.

Publications

- *«Mechanical behaviour and delamination mechanisms in temporary bonding», K. Vial et al, conference ESTC 2016, Grenoble, France.*
- *«Debonding capacity of mechanical debonding equipment depending on the bonding strength of directly and polymer bonded wafer pairs», K. Vial et al, conference Wafer Bond 2015, Braunschweig, Germany.*
- *«Polymer bonding temperature impact on the morphology and on the adherence energy of the bonded stack», P. Montméat et al, conference Wafer Bond 2015, Braunschweig, Germany.*
- *«Development and adhesion characterization of a silicon wafer for temporary bonding», P. Montméat et al, International Journal of Adhesion and Adhesives 82 (2018) 100–107.*

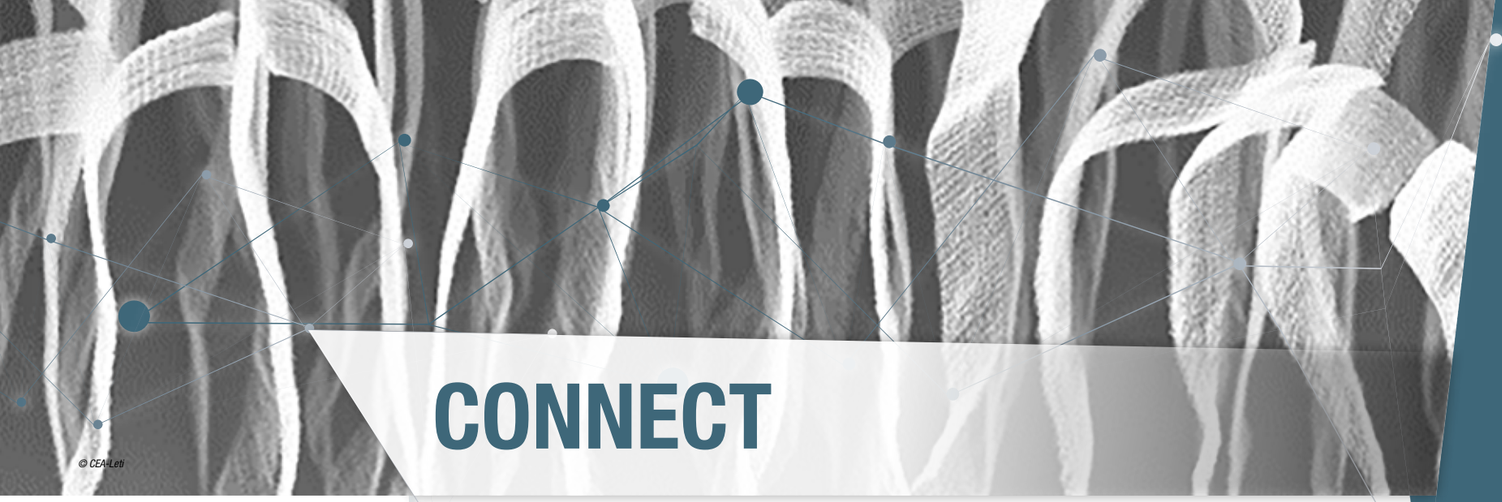
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Pierre Montmeat
pierre.montmeat@cea.fr

MICROELECTRONICS TECHNOLOGIES

CONNECT
ION4SET
NEREID
OCEAN 12

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CONNECT

Objectives

Modern society benefits enormously from novel miniaturised microelectronic products offering enhanced functionality at ever decreasing cost. However, as object size decreases, interconnects become major bottlenecks irrespective of the application domain. CONNECT investigated innovations in novel interconnect architectures to enable future CMOS scaling by integrating metal-doped or metal-filled Carbon Nanotube (CNT) composite. The project involved studying ultra-fine CNT lines and metal-CNT composite material for addressing the most imminent high power consumption and electro-migration issues of current state-of-the-art copper interconnects. Specific features were developed to improve resistivity (up to 10 µOhmcm for individual doped CNT lines) and both thermal and electro-migration properties with respect to state-of-the-art designs involving conventional copper interconnects. Furthermore, CONNECT developed novel CNT interconnect architectures to investigate circuit- and architecture-level performance and energy efficiency.

The technologies developed in this project are key to both the performance and manufacturability of scaled microelectronics, permitting higher power and scaling density of CMOS or CMOS extension and applicable to alternative concepts such as neuromorphic computing.

CONNECT

www.connect-h2020.eu

Keywords
Interconnection
Nanotubes

CONNECT at a glance

36 months
Jan.2016 > Dec. 2018

EC Programme
H2020 ICT-25-2015

Project Coordinator
Fraunhofer (DE)

Partners
CH: IBM
FR: CEA-Leti, CNRS
GB: Aixtron, Gold standard simulations, University of Glasgow

Total budget
€ 4 m.

EC Contribution
€ 3.4 m.

Contract Number
688612

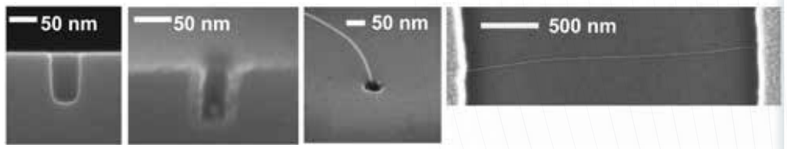
Carbon Nanotube Composite Interconnects

Billions of microscopic components such as transistors need to be interconnected within advanced electronic devices and these currently nanometer scale «objects» are shrinking every day! The CONNECT project focused on the performance of newly designed interconnections implementing combinations of carbon nanotubes embedded in a specific copper metallization protocol. From simulation to fabrication, the project partners were able to characterise new structures and assess a new technological interconnection path.

CEA-Leti in CONNECT

CEA-Leti contributed to CONNECT by implementing firstly advanced ebeam lithography then specific dry etching know-how to offer a wide range of nanometer length and depth features. CEA-Leti subsequently deposited a wide range of materials (including SiO2, Hf02, Al203, Si3N4, etc.) of different thicknesses to ascertain the best layer for optimised Carbon Nanotube growth inside small features. After the Carbon Nanotubes "forest" had been prepared for metallization, the CEA-Leti team conducted several experiments, based on electro-chemical deposition, to evaluate different metal sources. Its specific knowhow included catalysing of such advanced chemical reactions. Material screening was therefore undertaken for ranking at electrical test level after final process integration.

The main outcome of CONNECT was evaluation of combining specific carbon nanotubes with adaptive metallization for advanced interconnection to achieve unreached current densities in future chip connections. Metal line characteristics were specifically investigated to assess this unconventional approach in relation to future microelectronics. The latest result obtained was a current density of 10^8 A/cm² for a carbon nanotube with a diameter < 10 nm: one of the best results worldwide and outstanding for this ICT European project.



CNT interconnect ampacity > 10^8 A/cm².
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IMPACT

Efficient cooperation between CONNECT's European partners allowed wafer exchanges between facilities in different countries, paving the way for future cooperation in H2020, while envisioning the context of Horizon Europe and Digital Europe programs for 2021-2027. New process steps and related modules were assessed for interconnect metallization in relation to nanometer scale features. This benefits the European ecosystem and companies, which will take advantage of these new technological options in their R&D «tool box». The path towards directly reusing CONNECT project know-how will be facilitated, when new demonstrators have been envisaged by end-users.

Publications

- *«A Physics-Based Investigation of Pt-Salt Doped Carbon Nanotubes for Local Interconnects», J. Liang, R. Ramos, J. Dijon, H. Okuno, D. Kalita, D. Renaud, J. Lee, V. P. Georgiev, S. Berrada, T. Sadi, A. Asenov, B. Uhlig, K. Lilienthal, A. Dhavamani, F. Könemann, B. Gotsmann, G. Goncalves, B. Chen, K. Teo, R. R. Pandey, A. Todri-Sanial, in IEEE International Electron Devices Meeting (IEDM), December 2017, pp. 35.5.1-35.5.4. doi: 10.1109/IEDM.2017.8268502.*
- *"Challenges and Progress on Carbon Nanotube Integration for BEOL Interconnects (Invited)», B. Uhlig, A. Dhavamani, N. Nagy, K. Lilienthal, R. Liske, R. Ramos, J. Dijon, H. Okuno, D. Kalita, J. Lee, V. Georgiev, A. Asenov, S. Amoroso, L. Wang, F. Konemann, B. Gotsmann, G. Goncalves, B. Chen, J. Liang, R.R. Pandey, R. Chen, A. Todri-Sanial, in IEEE International Interconnect Technology Conference (IITC), June 2018.*
- *«Progress on Carbon Nanotube BEOL Interconnects», B. Uhlig, J. Liang, J. Lee, R. Ramos, A. Dhavamani, N. Nagy, J. Dijon, H. Okuno. D. Kalita, V. Georgiev, A. Asenov, S. Amoroso, L. Wang, C. Millar, F. Konemann, B. Gotsmann, G. Goncalves, B. Chen, R.R. Pandey, R. Chen, A. Todri-Sanial, in IEEE/ACM Design, Automation and Test in Europe Conference (DATE), March 2018, pp. 937-942. doi: 10.23919/DATE.2018.8342144.*
- *«Atomistic to Circuit Level Modeling of Defective Doped SWCNTs with Contacts for On-Chip Interconnect Application», J. Liang, J. Lee, S. Berrada, V. Georgiev, A. Asenov, N. Azemard-Crestani, A. Todri-Sanial, in IEEE Nanotechnology Materials and Devices Conference (NMDC), October 2017, pp. 66-67. doi: 10.1109/NMDC.2017.8350506.*

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Denis Renaud
denis.renaud@cea.fr

Yannick Le Tiec
yannick.letiec@cea.fr



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IONS4SET

Objectives

Billions of tiny computers that can sense and communicate from anywhere are coming online, creating the Internet of Things (IoT). As the IoT continues to expand, more and more devices require batteries and plugs. Gartner (www.gartner.com) states that there will be nearly 26 billion devices connected to the IoT by 2020. Together with improved batteries, advanced computation and communication must therefore be delivered at extremely low-power consumption. Single Electron Transistors (SETs) are extremely low-energy dissipation devices that are complementary with CMOS: the SET is champion of low-power consumption, while CMOS advantages, such as high speed, driving, etc., compensate perfectly for the SET's intrinsic drawbacks. Hybrid SET-CMOS architectures require unrivalled integration and high performance, while manufacturability remains a roadblock for the large-scale use of such architectures. To ensure room temperature (RT) operation, single dots with diameters < 5 nm need to be fabricated and precisely positioned between source and drain with tunnel distances of a few nm. However, a reliable CMOS compatible process for co-fabricating RT-SETs and FETs is not yet available. IONS4SET's SET nanopillar paved the way for fabricating low-energy devices operating at RT based on a newly developed bottom-up self-assembly process. Lithography cannot deliver the 1-3 nm feature sizes required for RT operation but IONS4SET provided:
1/ Controlled self-assembly of single ~ 2 nm Si dots and
2/ Self-alignment of each nanodot with source and drain at ~ 2 nm tunnel distances.
The Si nanodot fabrication process involved:
1/ Ion irradiation through thin (few tens of nm) Si pillars with an embedded SiO2 layer and
2/ Thermal activation of self-assembly.
Dot self-assembly works for narrow pillars only, hence nanopillar fabrication was crucial for IONS4SET. Finally, a power saving hybrid SET/CMOS device with a vertical gate-all-around nanowire GAA-SET was fabricated.

ions4SET

http://www.ions4set.eu

Keywords
Beyond CMOS
Gate All Around Nanopillars
Logic
Nanodot

IONS4SET at a glance

48 months (+6m)
Jan. 2016 > Jan. 2020

EC Programme
Horizon 2020(H2020) / ICT-25 (2015)

Project Coordinator
Helmholtz Zentrum Dresden Rossendorf (DE)

Partners
DE: Fraunhofer Institute for Integrated Systems and Device Technology, Helmholtz Zentrum Dresden Rossendorf (HZDR)
ES: Institute of Microelectronics Barcelona (CSIC)
FI: University of Helsinki
FR: CEA-Leti
IT: Consiglio Nazionale delle Richerche (CNR)

Total budget
€ 4 m.

EC Contribution
€ 4 m.

Contract Number
H2020, # 688072

Ion-irradiation-induced Si nanodot Self-Assembly for Hybrid SET-CMOS Technology

The aim of the IONS4SET project was to create single electron transistors for ultra-low power electronics so that the component using these optimized transistors delivers good performance at very low energy consumption. This type of transistor requires fabrication of nanopillars well beyond the state of the art, which implement a process compatible with the semiconductor industry (CMOS).

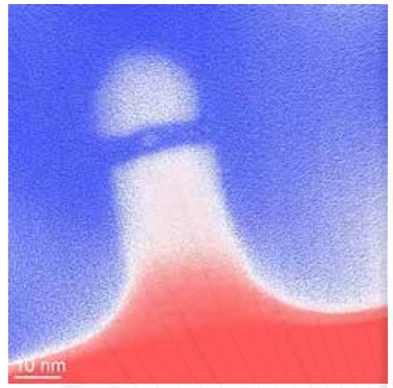
CEA-Leti in IONS4SET

The aim of the IONS4SET project was to develop a framework for reliably producing SETs that operate at room temperature using a semiconductor industry process flow. The final goal was a hybrid SET/FET electrical demonstrator.

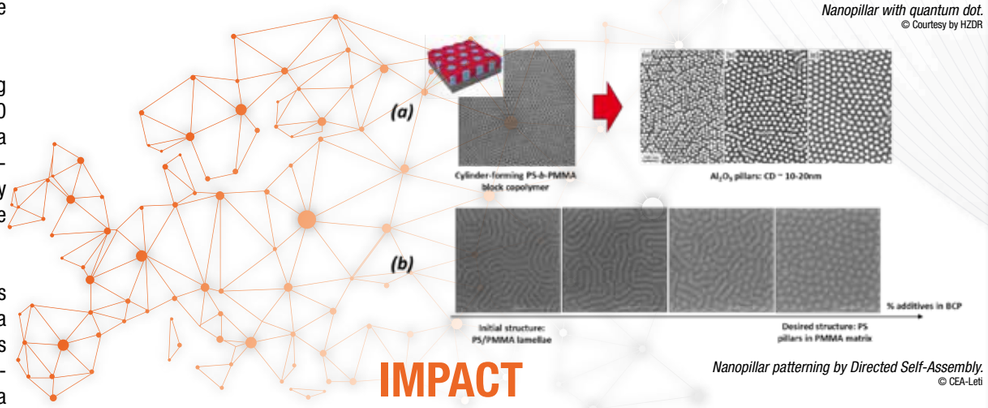
The SET was a 10 - 12 nm diameter Gate-All Around (GAA) nanopillar with a 6 nm embedded gate oxide (SiO2) layer. In this layer, a single 2 - 3 nm diameter silicon quantum nanodot (ND) was formed by Si+ ion implantation. During an annealing step, this silicon underwent phase separation and self-assembled into the ND. The bottom of the nanopillar was contacted electrically using the top-Si of an SOI advanced substrate.

Using its silicon platform, CEA-Leti patterned < 30 nm diameter nanopillars, while ensuring the deposition, implantation and annealing steps for integration reasons. 20 nm diameter, 70 nm high nanopillars were created by Electron Beam Direct Write (EBDW) and etched using a standard trilayer stack. We delivered wafers to the project partners for dicing, advanced characterization and electrical integration. Energy-Filtered Transmission Electron Microscopy (EFTEM) showed that the pillars were the right size and contained a single silicon ND in the embedded oxide.

CEA-Leti also investigated Directed Self-Assembly (DSA) of Block CoPolymers (BCP) as lithography for forming nanopillars. The first method involved forming PMMA contacts using a DSA contact shrink approach based on a PS-b-PMMA BCP. Sequential infiltration synthesis (SIS) was performed: Atomic Layer Deposition (ALD) was used to replace the PMMA with alumina (Al2O3), thus forming a hard mask for pillar patterning. The second method involved a PS-b-PMMA block copolymer with an inverse matrix for forming hexagonally organised sub-20 nm PS cylinders using a trilayer stack.



Nanopillar with quantum dot.
© Courtesy by HZDR



Nanopillar patterning by Directed Self-Assembly.
© CEA-Leti

IMPACT

The IoT demands ultra-low power electronics to improve battery life and lower carbon footprint. SETs promise to achieve those requirements because of the ultra-low current through such devices. The IONS4SET project combined fundamental physics of quantum devices and self-assembly with advanced 3D CMOS manufacturing at the 10 nm length scale. Industry interest was proven by external industry committee members GlobalFoundries, STMicroelectronics and X-Fab.

Publications

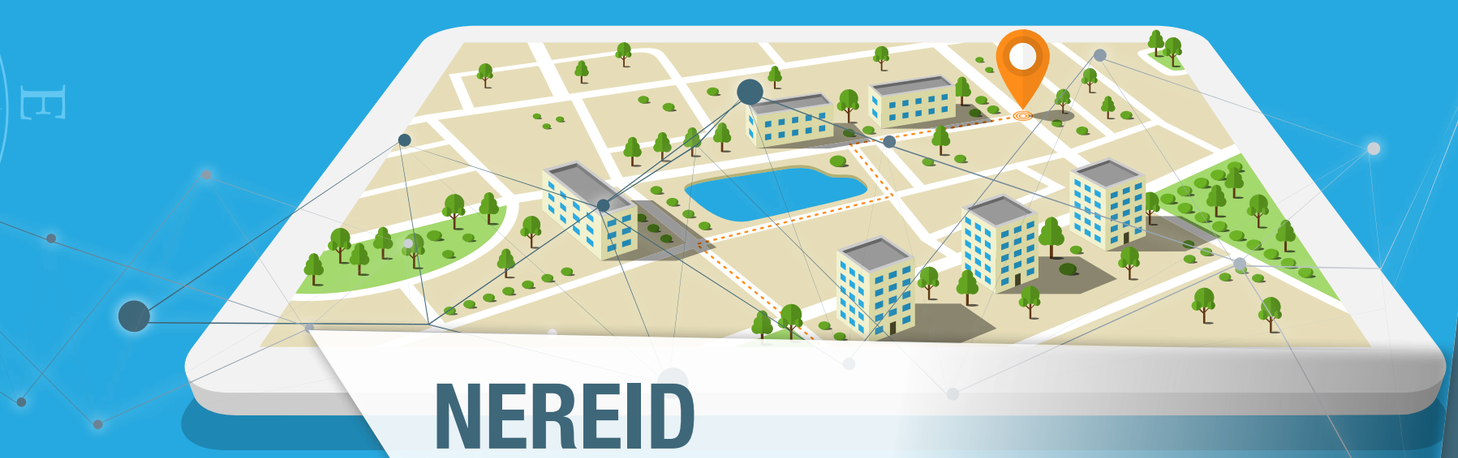
- *"Sub-20 nm multilayer nanopillar patterning for hybrid SET/CMOS integration", M.-L. Pourteau, A. Gharbi, P. Brianceau, J.-A. Dallery, F. Laulagnet, G. Rademaker, R. Tiron, H.-J.Engelmann, J. von Borany, K.-H.Heinig, M.Rommel, L.Baierd, Micro And Nanoengineering, (2020) Accepted paper.*
- *"Site-controlled formation of single Si nanocrystals in a buried SiO2 matrix using ion beam mixing", X. Xu, T. Prüfer, D. Wolf, H.-J. Engelmann, L. Bischoff, R. Hübner, K.-H. Heinig, W. Möller, S. Facsko, J. von Borany and Gr. Hlawacek, Beilstein Journal of Nanotechnology, 9, pp. 2883 (2018).*
- *"Exploring Strategies to Contact 3D Nano-Pillars", E. Amat, A. del Moral, M. Fernández-Regúlez, L. Evangelio, M. Lorenzoni, A. Garbi, G. Rademaker, M.-L. Pourteau, R. Tiron, J. Bausells, F. Perez-Murano, Nanomaterials, 10(4), pp. 716 (2020).*
- *"Effect of the Density of Reactive Sites in P(Sr-r-MMA) Film during Al2O3 Growth by Sequential Infiltration Synthesis", F.-E. Caligiore, D. Nazzari, E. Cianci, K. Sparnacci, M. Laus, M. Perego, G. Seguini, Advanced Materials Interfaces, 6(12), pp. 1900503 (2019).*
- *"A Compact Model Based on Bardeen's Transfer Hamiltonian Formalism for Silicon Single Electron T ransistors", F.-J. Klüpfel, IEEE Access, 7, pp. 84053 (2019).*

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Guido Rademaker
guido.rademaker@cea.fr

Raluca Tiron
raluca.tiron@cea.fr

Yannick Le Tiec
yannick.letiec@cea.fr



NEREID

Objectives

The NEREID project's aim is to develop a roadmap for the European nanoelectronics industry, starting from application needs and leveraging the strengths of the Europe's ecosystem. In addition, it will lead to early benchmarking/identification of promising new nanoelectronic technologies and will identify bottlenecks throughout the innovation (value) chain.

«http:// www.nereid-h2020.eu

Keywords
Nanoelectronics
Roadmap

NEREID at a glance

37 months
Nov. 2015> Dec. 2018

EC Programme
H2020-CSA-2015

Project Coordinator
Institut National Polytechnique de Grenoble (FR)

Partners
BE: IMEC
CH: Ecole Polytechnique Fédérale de Lausanne
EU: Aeneas, SINANO
FR: CEA-Leti
FI: VTT
GE: ECN, Fraunhofer
IR: Tyndall
IT: Polito, Iunet

Total budget
€ 1 m.

EC Contribution
€ 1 m.

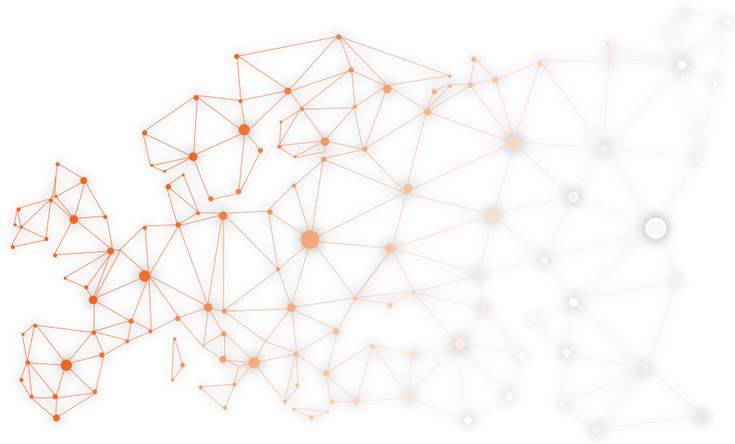
Contract Number
685559

NanoElectronics Roadmap for Europe: Identification and Dissemination

The NEREID project ("NanoElectronics Roadmap for Europe: Identification and Dissemination") is dedicated to mapping out the future of European nanoelectronics. Launched in November 2015, NEREID is a cooperation and support action that has received funding for three years from the European Union's Horizon 2020 research and innovation program under grant agreement No. 685559.

CEA-Leti in NEREID

CEA-Leti is leading work on applications related to sensors, smart energy devices and connectivity.



IMPACT

Many strategic and roadmap activities in micro- and nanoelectronics are in progress worldwide. Those that appear to be most important and to which the NEREID project results have contributed are:

- International Technology Roadmap for Semiconductors (ITRS)
- International Roadmap for Devices and Systems (IRDS)
- AENEAS Strategic Agenda
- ECSEL Multi Annual Strategic Plan
- CATRENE European Roadmap for Design Automation
- CATRENE White Book.

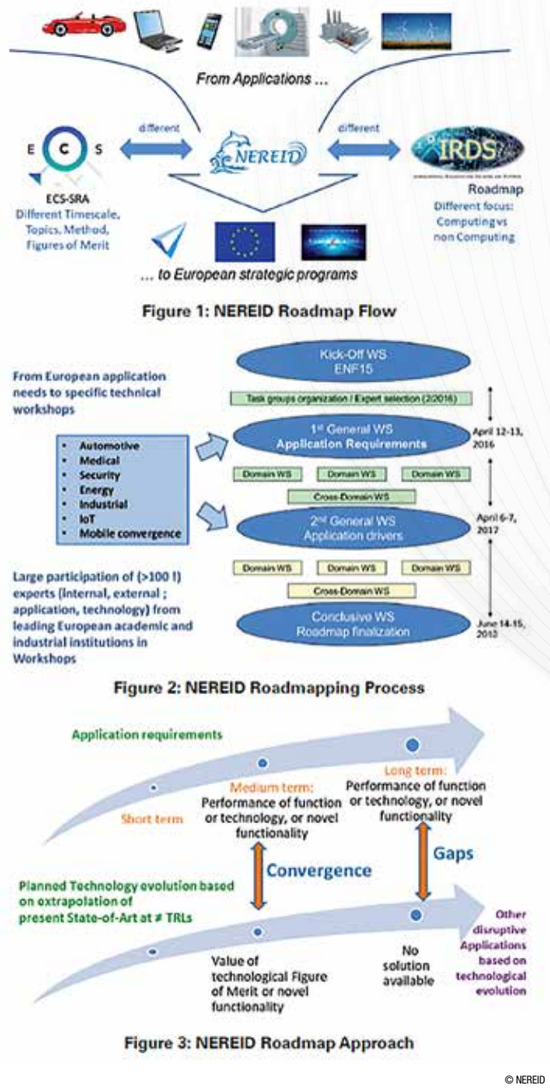


Figure 1: NEREID Roadmap Flow

Figure 2: NEREID Roadmapping Process

Figure 3: NEREID Roadmap Approach

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Publications

- *Deliverable 8.3: Technology Outlook in Nanoelectronics and harmonization of NEREID roadmaps with International Roadmaps*
  Montserrat Fernandez-Bolanos Badia, École Polyt...
  Mihai Adrian Ionescu, ECOLE POLYTECHNIQUE FEDER...
  2018/05/15
- *Deliverable 7.4.: Dissemination, Communication and Data Management plan update Ralf Popp, edacentrum GmbH, DE*
  2017/11/15
- *Deliverable 7.3: First Roadmap Release Ralf Popp, edacentrum GmbH, DE*
  2017/09/01
- *Deliverable 8.2: Mapping of International Roadmap Activities Mihai Adrian Ionescu, ECOLE POLYTECHNIQUE FEDER...*
  2017/02/15
- *Deliverable 8.1: NEREID Advisory Comitee*
  Mihai Adrian Ionescu, ECOLE POLYTECHNIQUE FEDER...
  Francis Balestra, INSTITUT POLYTECHNIQUE DE GRE...
  2016/09/06
- *Deliverable 7.2: Dissemination, Communication and Data Management plan*
  Ralf Popp, edacentrum GmbH, DE
  Jürgen Haase, edacentrum GmbH, DE
  Francis Balestra, INSTITUT POLYTECHNIQUE DE GRE...
  Sylvie Pitot, Grenoble INP, FR
  Pascale Caulier, SINANO Institute, FR
  2016/08/30
- *Deliverable 5.1: Report on Workshop 1 and their impact to system integration, and case studies for Task specific Workshops*
  Danilo Demarchi, POLITECNICO DI TORINO, IT
  Ralf Pferdmenges, Infineon Technologies AG, DE
  Clement Benoit 2016/08/07
- *Deliverable 1.2: Roadmap priorities from 1st General Workshop with applications*
  Enrico Sangiorgi, INSTITUT SINANO ASSOCIATION, FR
  Francis Balestra, INSTITUT POLYTECHNIQUE DE GRE...
  Pascale Caulier, SINANO Institute, FR
  Sylvie Pitot, Grenoble INP, FR
  2016/06/15
- *Deliverable 7.1: Web-site available on line Ralf Popp, edacentrum GmbH, DE*
  2016/05/15

David Holden
David.holden@cea.fr

Didier Belot
didier.belot@cea.fr



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OCEAN12

https://www.ecsel.eu/projects/ocean12

Keywords
Automotive Autonomous driving
Design technology
Electrical engineering
Electronic engineering
FDSOI
Information engineering
Nanotechnology
Semiconductor process equipment and materials
Smart mobility
Smart system integration

OCEAN12 at a glance

45 months
Apr. 2018 > Dec. 2021

EC Programme
H2020-ECSEL

Project Coordinator
Soitec (FR)

Partners
AT: EVG
DE: Airbus, AED, AUDI, Bosch, University of Tübingen (EKUT), Fraunhofer, GF, HSEB, MunEDA, Technische Universität Dresden, Universität der Bundeswehr München, Universität Paderborn
EL: ISD SA
ES: EVOTEL Informatica SL
FR: CEA-Leti, D&R, IBS, Institut National Polytechnique Grenoble, IMS, Kalray, M3S, Soitec, STMicroelectronics, Thales

Total budget
€ 103.6 m.

EC Contribution
€ 24.03 m.

Contract Number
783127

Opportunity To Carry European Autonomous Driving Further with FDSOI Technology up to 12nm Node

The OCEAN12 project is developing an innovative FDSOI platform in response to the strategic challenges of smart mobility. Overall, the project involves setting up an advanced SOI pilot line, defining FDSOI pathfinding solutions to push performance, developing innovative designs and manufacturing high performance ICs.

CEA-Leti in OCEAN12

CEA-Leti's contribution to OCEAN12 embraces two areas: the SOI technology platform and design work.
Regarding the SOI technology platform, CEA-Leti is developing pathfinding solutions to push 12FDX technology performance. **These solutions are divided between two areas of research:**

- At device level: evaluation of disruptive processes to boost device performance; several approaches are being implemented in parallel.
  - > SiN stress change by plasma treatment: this concept is being developed with IBS; It takes advantage of Plasma Immersion Ion Implantation capability. The method's ability to transform SiN layer stress from tension to compression has been demonstrated and it opens up the path to innovative dual CESL integration.
  - > MOL: for the first time, a morphological evaluation of F-free W liner compared with a conventional TiN liner has been conducted on FDSOI lots. Encouraging morphological results have been achieved and electrical packages are ongoing to quantify the related performance gain.
  - > BOX Creep: the ability of this innovative strain engineering technique to boost pMOS performance has been quantified for a wider thermal budget window. For the first time, BOX Creep is also being studied using TiN, which offers a new solution to boosting nMOS performance.
- At substrate level: development of an innovative substrate process to boost performance and improve the SOI quality.
  - > An alternative SOI process using an EPI-based donor, has been demonstrated for controlling SOI thickness and roughness without the need for high temperature or CMP finishing.
  - > Understanding the fracture dynamic is of prime interest because this can affect the SOI morphology. A method for imaging fracture propagation in situ has been developed based on synchrotron radiation.

Regarding design work:

- Work has mainly focused on defining awakening system architecture on wake-up radio. Together, we decided to optimize overall architecture, building block specifications and the protocol. New methodology, taking into account SOI technology capacity, has been developed for this purpose; this has led to System Technology Co-Optimization.
- For the wake-up imager, we have investigated various types of data modalities and acquisition types by developming experimental platforms to prepare future needs. The exponential complexity has been defined to make Global Localization implementable on low capability computing platforms. The new algorithm has been tested on a real floorplan and on a learned cluttered map.

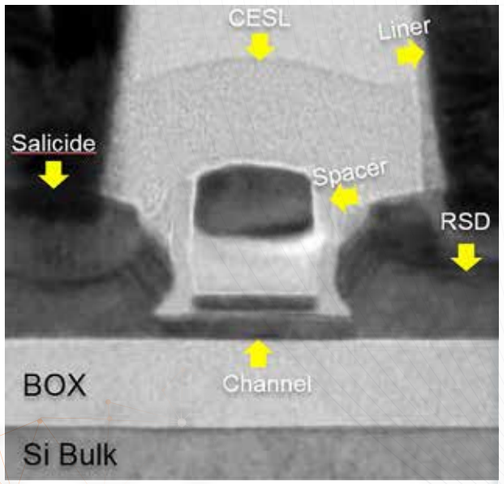
Objectives

OCEAN12 targets the key societal challenge of smart mobility. Based on innovative FDSOI technology, OCEAN12 will develop new processors and applications that leverage Fully Depleted Silicon On Insulator (FD-SOI) technology to offer the industry's lowest power consuming processor for automotive and aeronautic applications, in particular.

OCEAN12 will develop a technology platform benefitting from the extreme low leakage and operating voltage (Vdd) scalability of FDSOI design, which will be achieved by reverse and forward body biasing (RBB/FBB) of the integrated circuit and its power system architecture. This high performance, low power solution will equip the upcoming strategic generations of smart vehicles. The platform will rely on:

- Pilot line facilities capable manufacturing advanced substrates compatible with 12FDX technology and defining pathfinding solutions to push 12FDX technology performance and innovative sensor development
- Development of innovative designs to enhance FDSOI capacity and guarantee the highest level of integrated solutions
- Manufacturing high performance ICs using every feature of FDSOI technologies.

The highly integrated, reliable, ultra low power and cheaper components will be integrated into complex embedded systems accessible to TIER-1, 2 and OEMs to meet the strategic challenges of future vehicles. Several product demonstrators are targeted including a high end microcontroller plug-and-play board, high-performance sensor data fusion, highly integrated low power video processing and awaking systems. This project creates a high added value network to strengthen a competitive European value chain on a European breakthrough and secure a unique FDSOI roadmap beyond the 22FDX. Finally, OCEAN 12 highlights Europe's unique leading position in FDSOI technology by integrating the entire manufacturing chain, from substrate suppliers and foundries to TIER-1 and OEM - including academia and RTO's - into this dynamic.



Location of the performance boosters developed into OCEAN12 (cross section from R. Carter et al., IEDM'16).
© CEA-Leti

IMPACT

Through these studies of the 12nm node, OCEAN12 paves the way to creating necessary momentum to offer FDSOI the possibility of developing technologies manufactured in Europe for a sub-20nm node or even below. OCEAN12 promotes a close relationship between major European industrials, including end users, SME's and academics, to establish a unique European network of FDSOI excellence specifically in the service of autonomous mobility applications. It provides CEA-Leti with the opportunity to realize advanced developments in the materials and substrates needed for the 12nm node in cooperation with SOITEC and to prepare the related technological bricks in connection with Global Foundries.

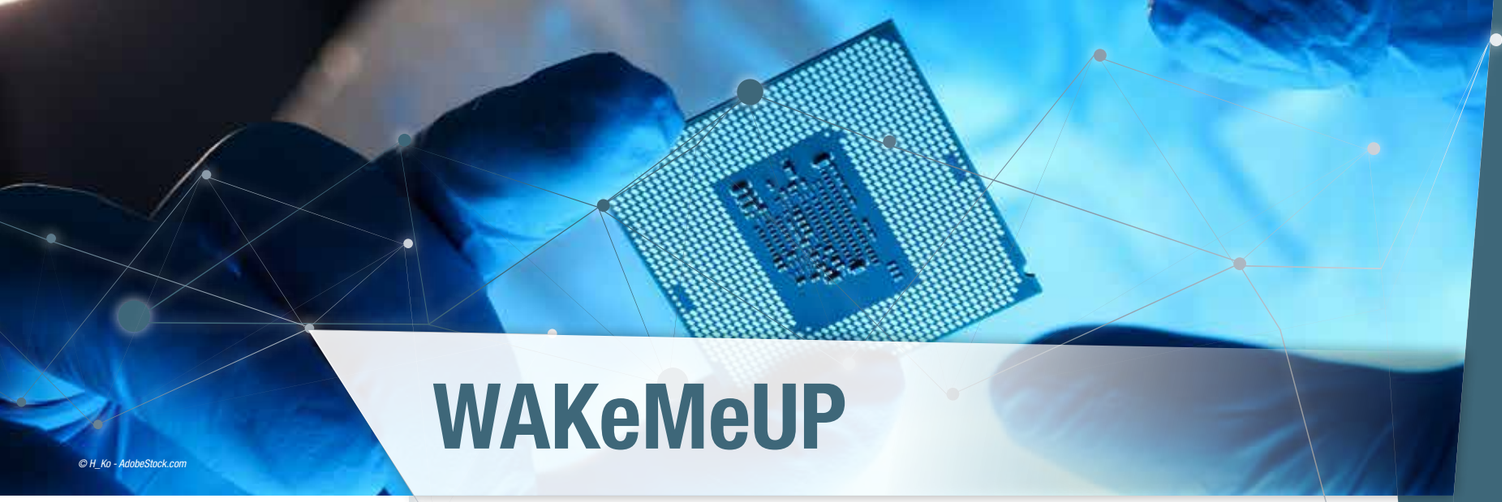
Publications

• *«Crack Front Interaction with Self-Emitted Acoustic Waves», D. Massy, F. Mazen, D. Landru, N. Ben Mohamed, S. Tardif, A. Reinhardt, F. Madeira, O. Kononchuk, and F. Rieutord, PHYSICAL REVIEW LETTERS 121, 195501 (2018).*

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Christophe Plantier
christophe.plantier@cea.fr

Yves Quéré
yves.quere@cea.fr



WAKeMeUP

Wafers for Automotive and other Key applications using Memories, embedded in Ulsi Processors

The aim of the WAKeMeUp project is to set up a complete manufacturing platform for non-volatile embedded Phase Change Memories. This disruptive memory technology will be embedded on 28nm FDSOI logic for a new generation of microcontrollers.

https://www.ecsel.eu/projects/wakemeup

Keywords
Ferroelectric Random Access Memory (FeRAM)
Memory
MicroController Unit (MCU)
Microelectronics
Neuromorphic
Oxide-based resistive RAM (OXRAM)
Phase Change Memory (PCM)

WAKeMeUP at a glance

36 months
May 2018 > Apr. 2021

EC Programme
ECSEL IA- 2017

Project Coordinator
STMicroelectronics (FR)

Partners
DE: CONTI, FhG-IPMS, TUDarm, X-Fab, MLX
FR: CEA-Leti, CNRS-LTM, GEMALTO, Pfeiffer, ST-CRO, ST-GRE, ST-LEM, ST-ROU, ST-SA
CZ: UTIA, IMA
TR: Tubitak
SP: UAB

Total budget
€ 96.6 m.

EC Contribution
€ 24.4 m.

Contract Number
783176

CEA-Leti in WAKeMeUP

CEA-Leti is pushing the performance of embedded PCM (ePCM) in terms of scalability, power consumption, reliability and compatibility with CMOS.

Two major strategies have been defined for improving PCM performance in terms of programming current reduction and enhancing heat confinement of the active cell volume:

• Material investigation on a standard cell structure. An outstanding improvement in 4 kbit PCM programming and retention performance has been achieved by integrating a low thermal conductivity, SiC-based encapsulation layer. SiC PCM features included lower programming currents (~20% of reduction compared to SiN-PCM), higher programming speed (~35% faster than SiN-PCM) with data retention of more than 1 hour at 250°C

• New cell structure investigation. A novel architecture has been successfully fabricated with PCM material deposited using an «S-shape» structure. We have demonstrated a sixfold reduction in terms of programming current density compared with the classical heater structure.

Objectives

The aim of the WAKeMeUp project is to set up a pilot line for advanced microcontrollers with embedded non-volatile memories, to design and manufacture the prototypes for innovative applications in the areas of smart mobility and smart society.

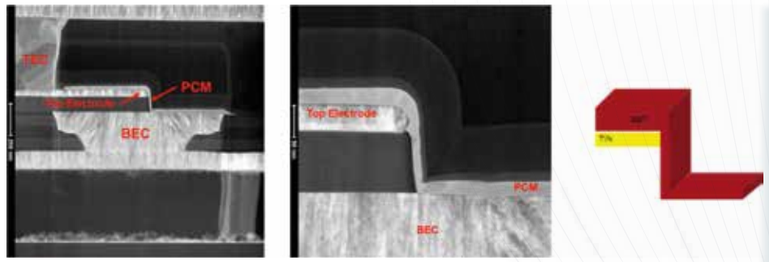
The project is targeting industrialization of embedded Phase Change Memory (ePCM) technology built on the FDSOI 28nm logic process pilot line. ePCM development is driven by final application needs and reduction of power consumption.

Existing microcontrollers with 40nm embedded flash technology have been consolidated to build a solid manufacturing platform. Additional developments have included integration of memory, power management, connectivity and strong security into the same chip.

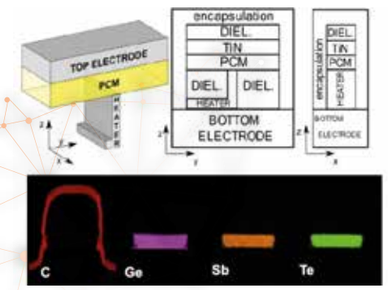
Alternative memory solutions have also been studied; they have different, complementary properties in areas such as read/write speed, power and energy consumption, retention and endurance and device density and are benchmarked with the ePCM and conventional eFlash. Continued improvements in materials, device physics, architectures and design could further reduce the energy consumption of these memories.

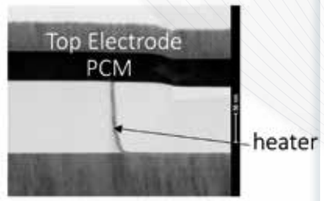
The project is deploying all the necessary operations to bring a new technology to early industrial maturity in order to achieve creation of high added value semiconductor circuits in Europe based on breakthrough leading edge technology. These operations encompass developments such as enhanced technology for specific application requirements including wide temperature ranges (up to 165°C) and reliability, high security demands and high flexibility. Design enablement has led to first time silicon success and prototyping of demonstrator products for Smart Mobility and Smart Society.

The WAKeMeUp project has allowed new devices and devices to be developed by the application partners in the automotive and security sectors based on FD-SOI and embedded digital technology that meets specific application needs (power/perfomance/costs).



TEM images of a Self-heating structure fabricated at CEA-Leti using MAD200 platform: PCM material is deposited in a "S shape", hence optimizing thermal confinement. TEC (BEC) stands for Top (Bottom) electrode. Simplified description of the "S-shape" structure (right).
© CEA-Leti





Simplified description of the heater-based PCM device (top left). TEM/EDX analysis of the encapsulation layer and of the PCM layer (bottom left). STEM analysis of the heater and PCM device (right).
© CEA-Leti

IMPACT

The WAKeMeUp project will reinforce STMicroelectronics leadership in the microcontroller semi-conductor industry especially in the automotive field.

The project will generate benefits for the European Member States taking part, either in relation to production facilities and/or in academic know-how, and it is expected to have a positive effect on the labor market. Initial application will be in Europe, followed by introduction worldwide.

Publications

• «Optimized Reading Window for Crossbar Arrays Thanks to Ge-Se-Sb-N-based OTS Selectors», A. Verdy and all, IEDM, San Francisco, 01-05 December 2018.
• «Phase-Change Memory: Performance, Roles and Challenges», G. Navarro and all, IMW, Kyoto, 13-16 June 2018.

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1 2 3 4 **5 6 7 8** 9

Christelle Charpin-Nicolle
christelle.charpin@cea.fr

Yves Quéré
yves.quere@cea.fr


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Management


© P. Jayet

Emmanuel Sabonnadière

Chief Executive Officer


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Jean-René Lequepeys

Deputy Director -
Chief Technology Officer


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Communications
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Director IRT Nanoelec


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Carlo Reita

Director, strategic partnerships
and planning, CTO office


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Michael Tchagaspanian

Executive VP Sales &
Technical Marketing


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Thomas Signamarcheix

VP Strategic development,
CTO office


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Fabrice Geiger

Head of Investment and
Supplier Partnership Group


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Clinatec Endowment Fund


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Sylvain Colomb

Startup Program

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CONTACTS

Laurent Hérault
VP for Europe
laurent.herault@cea.fr

Yannick Le Tiec
Silicon Technologies
yannick.letiec@cea.fr

Yves Queré
Jean-Charles Barbe
Silicon Components
yves.quere@cea.fr
jean-charles.barbe@cea.fr

Didier Belot
Architecture and IC Design, Embedded Software
didier.belot@cea.fr

Laurent Fulbert
Optics and Photonics
laurent.fulbert@cea.fr

Caroline Desvergne
Abdelmadjid Hihi
Technologies for Biology and Health
caroline.desvergne@cea.fr
abdelmadjid.hihi@cea.fr

Bernard Strée
Systems and Solutions Integration
bernard.stree@cea.fr

Editorial line: **Laurent Herault**
Editorial team: **Yannick le Tiec, Jean-Charles Barbe, Didier Belot, Laurent Fulbert, Caroline Desvergne, Abdelmadjid Hihi, Yves Queré, Bernard Strée**
Communication and coordination: **Hélène Vatouyas**
Design: **Valérie Lassablière**
Editorial contributions: **Philip Cannell (Cabinet Bingel-Cannell), Sara Freitas, SFM Traduction**



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MINATEC Campus | 17 avenue des Martyrs | 38054 Grenoble cedex 9 | France
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