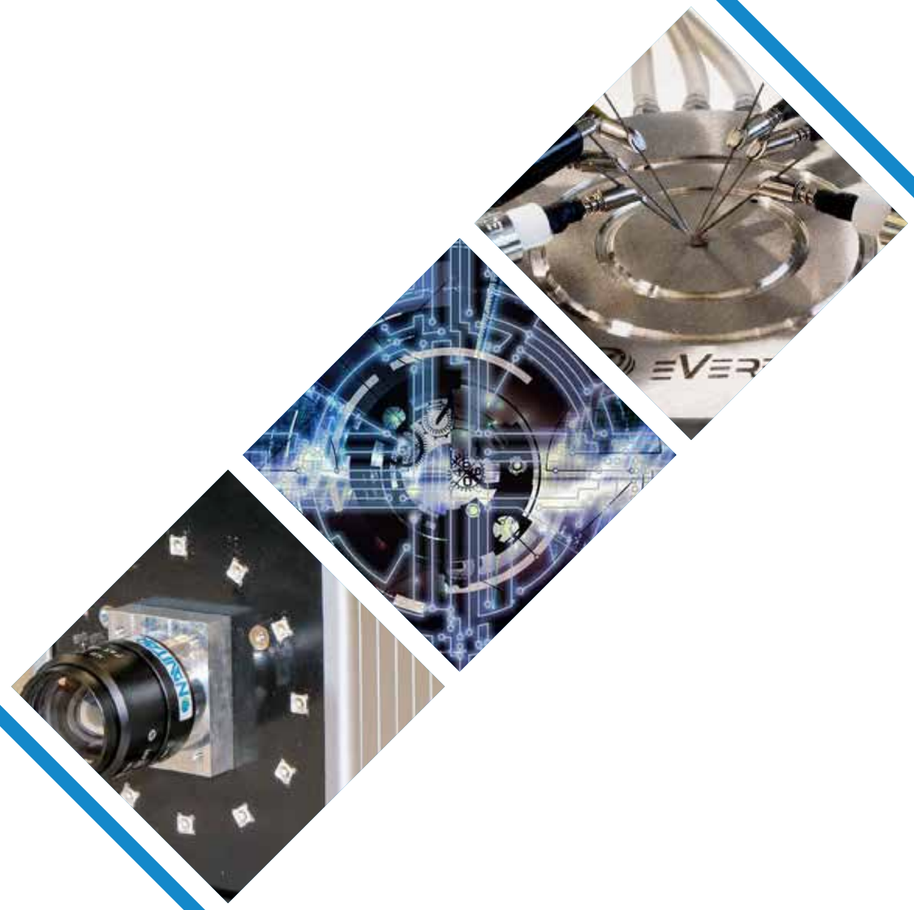
Science for Peace and Security (SPS) Cluster Workshop on Advanced Technologies

Under the auspices of

KU LEUVEN

Leuven, Belgium
17/18 september 2019

NATO Emerging Security Challenges (ESC) Division



INTRODUCTION

Dear Participants,

Welcome to the NATO Science for Peace and Security (SPS) Programme "Cluster Workshop on Key Priority Area Advanced Technologies", organized in cooperation and under the auspices of the Katholieke Universiteit Leuven.
The Workshop will cover selected projects in the field of security-related advanced technologies supported by the NATO SPS Programme, in particular **communication systems**, **new materials**, **sensors and detectors**, and **unmanned and autonomous systems**.
The main goal of this workshop is to find out how SPS projects contribute to the development of scientific and technical knowledge in those fields. The findings of the workshop will help NATO SPS to promote future actions in the SPS Key Priority Area Advanced Technologies.

AGENDA

17 September 2019

09:30 – 10:00 **Registration**

Session 1: Introductory remarks

Moderator: Claudio Palestini, *NATO*

10:00 – 10:30 **Opening Addresses**

Dr. Antonio Missiroli, *Assistant Secretary General, Emerging Security Challenges Division, NATO*
Prof. Sofie Pollin, *KU Leuven, Belgium*

10:30 – 10:50 **The Science for Peace and Security Programme**

Dr. Deniz Beten, *Senior SPS and Partnership Cooperation Advisor, Emerging Security Challenges Division, NATO*

10:50 – 11:10 **Coffee Break**

Session 2: Communication Systems

Moderators: Sofie Pollin, *KU Leuven* – Claudio Palestini, *NATO*

11:10 – 11:30 **G5461 - Large Scale Collaborative Detection and Location of Threats in the Electromagnetic Space (SOCRATES)**

Dr. Domenico Giustiniano, *IMDEA Networks Institute, Spain*
Dr. Vincent Lenders, *Electrosense, Switzerland*
Prof. Sofie Pollin, *KU Leuven, Belgium*

11:30 – 11:50 **G5482 - Public Safety COmmUNication in ConTExt Related to Terror Attacks (Counter-Terror)**

Dr. Muhammad Mahtab Alam, *Tallinn University of Technology, Estonia*
Dr. Rizwan Ahmad, *School of Electrical Engineering and Computer Science, National University of Sciences and Technology (NUST), Pakistan*
Dr. Maurizio Magarini, *Politecnico di Milano, Italy*

11:50 – 12:10 **G5269 - Flash Crowds Management via Virtualized Network Resources (FALCON)**

Prof. Alberto Leon-Garcia, *University of Toronto, Canada*
Prof. Liljana Gavrilovska, *Ss. Cyril and Methodius University in Skopje, North Macedonia*

12:10 – 12:30 **G5319 - Threat Predict: From Global Social and Technical Big Data to Cyber Threat Forecast**

Dr. Jérôme François, *INRIA, France*
Dr. Ghita Mezzour, *International University of Rabat, Morocco*

12:30 – 13:30 **Lunch** - **Demonstration of Project G5461 - SOCRATES**

13:30 – 13:50 **G5263 - Analysis, Design and Implementation of an End-to-End 400km QKD Link**

Dr. Marina Mondin, *California State University, Los Angeles (CSULA), USA*

13:50 – 14:10 **G5448 - Quantum-safe Authenticated Group Key Establishment**

Dr. Rainer Steinwandt, *Florida Atlantic University, USA*

14:10 – 14:30 **G5485 - Secure Quantum Communication Undersea Link**

Prof. Andre Xuereb, *University of Malta, Malta*

14:30 – 15:00 **Round Table Discussion:**

Contributions of SPS Programme to the Field of Communication Systems
Recommendations for future SPS Activities

15:00 – 15:20 **Coffee Break**

Session 3: Innovative and advanced materials

Moderators: Ivana Capan, *Rudjer Boskovic Institute* - Claudio Palestini, *NATO*

15:20 – 15:40 **G5215 - Engineering Silicon Carbide for Enhanced Border and Port Security (E-SiCure)**

Dr. Ivana Capan, *Rudjer Boskovic Institute, Croatia*

15:40 – 16:00 **G5120 - Infrared Transparent Ceramic Windows for High-speed Vehicles**

Dr. Mathias Hermann, *Fraunhofer Institute of Ceramic Technologies and Systems, Germany*
Prof. Andrey Ragulya, *National Technical University of Ukraine, Ukraine*

16:00 – 16:20 **G5140 - Advanced Nanotechnologies For Multivariate Sensor Fabrication**

Dr. Andrea Goldoni, *Elettra - Sincrotrone Trieste, Italy*
Dr Borys Snopok, *V.Ye. Lashkarjov Institute of Semiconductor Physics National Academy of Science of Ukraine, Ukraine*
Dr. Alberto Verdini, *Istituto Officina dei Materiali, Consiglio Nazionale delle Ricerche (CNR), Italy*

16:20 – 16:40 **G5453 - Radiation Hard UV Detectors against Terrorist Threats**

Dr. Igor Lubomirsky, *Weizmann Institute of Science, Israel*
Mr. Sergey Khodorov, *Weizmann Institute of Science, Israel*

16:40 – 17:00 **G5580 - Creation of New Generation Titanium Diboride Composite Armour Material**

Dr. Gabriel Benga, *University of Craiova, Romania*

17:00 – 17:20 **G5030 - Titanium Armour with Gradient Structure: Advanced Technology for Fabrication**

Dr Sergey Prikhodko, *University of California Los Angeles, USA*

17:20 – 17:50 **Round Table Discussion:**

Contributions of SPS Programme to the Field of Innovative and advanced materials
Recommendations for future SPS Activities

17:50 – 18:00 **Practical information - End of Day 1**

18:30 – 21:00 **Working Dinner**

AGENDA

18 September 2019

09:30 – 10:00 **Registration**

10:00 – 10:20 **Sum-up of Day 1 and Introduction of Day 2**
Dr. Claudio Palestini, *NATO*

Session 4: Sensors and Detectors

Moderators: Eyup Turmus, *NATO* - Claudio Palestini, *NATO*

10:20 – 10:40 **G5267 - Maritime Security - Multistatic and Multiband Coherent Radar Fleet for Border Security (SOLE)**
Dr. Giovanni Serafino, *Inter-University National Consortium for Telecommunication (CNIT), Italy*
Dr. Steve Lecomte, *Centre Suisse d'Electronique et de Microtechnique, Switzerland*

10:40 – 11:00 **G5465 - Noise Imaging Radar Network for Covert Air and Maritime Border Security (NORMA)**
Dr. Sonia Tomei, *Radar and Surveillance System (RaSS) National Lab – CNIT, Italy*

11:00 – 11:30 **Coffee Break**

11:30 – 11:50 **G5248 - Compact Eye-Safe Lidar Source for Airborne Laser Scanning (CALIBER)**
Dr. Nadia Boetti, *Links Foundation, Italy*
Prof. Amiel Ishaaya, *Ben-Gurion University of the Negev, Israel*

11:50 – 12:10 **G4840 - Microelectronic 3D Imaging and Neuromorphic Recognition for Autonomous UAVs**
Prof. Jean-Michel Redouté, *Université de Liège, Belgium*

12:10 – 12:30 **G5437 - Wide InTegration of sensor Networks to Enable Smart Surveillance (WITNESS)**
Dr. Alessandro Mattiacci, *Link Campus University, Italy*

12:30 – 13:30 **Lunch**

13:30 – 13:50 **G5244 - Graphene / Polymer based Sensor**
Dr. Radmila Tomovska, *Universidad del Pais Vasco, Spain*
Dr. Jadranka Blazevska-Gilev, *University St. Cyril and Methodius, Faculty of Technology and Metallurgy, North Macedonia*

13:50 – 14:10 **G5351 - Nanocomposites Based Photonic Crystal Sensors of Biological and Chemical Agents**
Dr. Pavlo Yezhov, *Institute of Physics of National Academy of Sciences of Ukraine, Ukraine*

14:10 – 14:40 **Round Table Discussion:**
Contributions of SPS Programme to the Field of Sensors and Detectors
Recommendations for future SPS Activities

Session 5: Unmanned and autonomous systems

Moderators: Herman Deconinck, *von Karman Institute for Fluid Dynamics* – Claudio Palestini, *NATO*

14:40 – 15:00 **G5176 - Agile Tyre Mobility for Severe Terrain Environments**
Dr. Vladimir Vantsevich, *University of Alabama at Birmingham, USA*
Dr. Lyubomyr Demkiv, *Lviv Polytechnic National University, Ukraine*

15:00 – 15:20 **G5293 - Autonomous Platform for Securing Marine Infrastructures**
Dr. Paolo Casari, *IMDEA Networks Institute, Spain*
Dr. Roee Diamant, *University of Haifa, Israel*

15:20 – 15:40 **G5322 - High Altitude Balloon-Borne Radar**
Prof. Marco Martorella, *University of Pisa, Italy*

15:40 – 16:00 **G5428 - Dynamic Architecture based on UAVs Monitoring for Border Security and Safety**
Prof. Fabrizio Granelli, *Università di Trento (UNITN), Italy*

16:00 – 16:20 **G5568 - Mobile Adaptive/Reactive Counter Unmanned Aerial System (MARCUS)**
Dr. Markus Höpflinger, *Armasuisse, Switzerland*

16:20 – 16:50 **Round Table Discussion:**
Contributions of SPS Programme to the Field of Unmanned and autonomous systems
Recommendations for future SPS Activities

16:50 – 17:00 **Conclusions**
Dr. Deniz Beten, *Senior SPS and Partnership Cooperation Advisor, Emerging Security Challenges Division, NATO*

Summary of SPS Multi-Year Projects on Advanced Technologies

G5461 - Large Scale Collaborative Detection and Location of Threats in the Electromagnetic Space (SOCRATES)

Dr. Domenico Giustiniano,
IMDEA Networks Institute, Spain
Dr. Vincent Lenders,
Electrosense, Switzerland
Prof. Sofie Pollin,
KU Leuven, Belgium

In the 21st century, the security of the electromagnetic spectrum has tremendous strategic importance to society. In particular, the wireless infrastructure that carries vital services such as 5G cellular networks, communication to space and Global Positioning System is especially critical. This rapid change is even more impressive considering that in the 80s the only concern for spectrum management was mostly about radio/television broadcasting and military communications. The allocation of spectrum has become over the years more and more complex with different players and stakeholders that depend largely of their correct operation. Today, the cost of commodity radio technology prices is so low that access to it is no longer restricted to governments and network operators. It is now affordable to individuals, giving them the potential to become malicious intruders. More frequent and more sophisticated threats from such infiltrators could wreak havoc and are among the most serious challenges faced by society. Unauthorized transmissions could threaten the operation of networks used by air traffic control systems, police, security and emergency services, for example. The SPS project G5461 SOCRATES (Large Scale Collaborative Detection and Location of Threats in the Electromagnetic Space, Grant) project started in June 2018 and aims to deliver a security system to protect our electromagnetic environment and the services and users that depend upon it. SOCRATES provides an accurate, autonomous, fast and secure system based on a novel and disruptive IoT (Internet of Things) architecture. By detecting and locating unusual RF signal and source activity it identifies intruders in the electromagnetic space, before a threat can become serious, learning about its physical layer features and its geographic location.

G5482 - Public Safety COmmUNication in ConTExt Related to Terror Attacks (Counter-Terror)

Dr. Muhammad Mahtab Alam,
Tallinn University of Technology, Estonia
Dr. Rizwan Ahmad,
School of Electrical Engineering and Computer Science,
National University of Sciences and Technology (NUST), Pakistan
Dr. Maurizio Magarini,
Politecnico di Milano, Italy

The increasing number of terrorist attacks and fatalities have raised serious concerns for the entire world. One of the fundamental issues in most of the terrorist attacks is the slow response time as it is observed that, even after many hours, police and other law enforcement agencies are often unable to take actions against terrorists due to the lack of basic information such as the number of people trapped inside the attacked zone, their location and identity, the number of terrorists and their locations, etc.

The SPS project G5482 "Public Safety COmmUNication in ConTExt Related to Terror Attacks (Counter-Terror)" is to provide innovative answers and solutions to the problem "how to reduce the response time in the context of terrorist attacks?" As of today, from an information and communication technology (ICT) viewpoint, classical public safety networks (PSNs) do not provide the appropriate infrastructure to deal with these attacks. This is because such networks are not designed i) for the specific context of terrorist attacks, and ii) to exploit the devices (in particular user equipment) and networks, which are active, and already inside the terror zone (e.g., shopping mall, theatre etc.). These requirements are different from classical PSNs since a) in typical natural disasters, the emergency rescue teams can gain access into the disaster site during or after the emergency incident with only slight (if not without) direct life threat and can start the operations immediately, whereas in the case of terrorist attacks, rescue and law enforcement teams remain unable to immediately step-in because of the unclear information and the situational facts (i.e., number of terrorists, their positions, the number and type of weapons used and severe consequences, etc.), and b) in terrorist attacks, the devices held by the people are critical (for example, their personal ID number and name can be traced through the device ID and this can further help to provide the exact location of the persons). In addition, other important information about the devices such as battery levels, devices radio-link conditions, signal strengths and connectivity patterns, as well as mobility profiles can be traced autonomously. In this work, we are developing methods and techniques to exploit smartphones and/or on-scene available (OS-A) devices, which have enabled direct communication feature in the affected zone, to get the fundamental and critical information to reduce the response time.

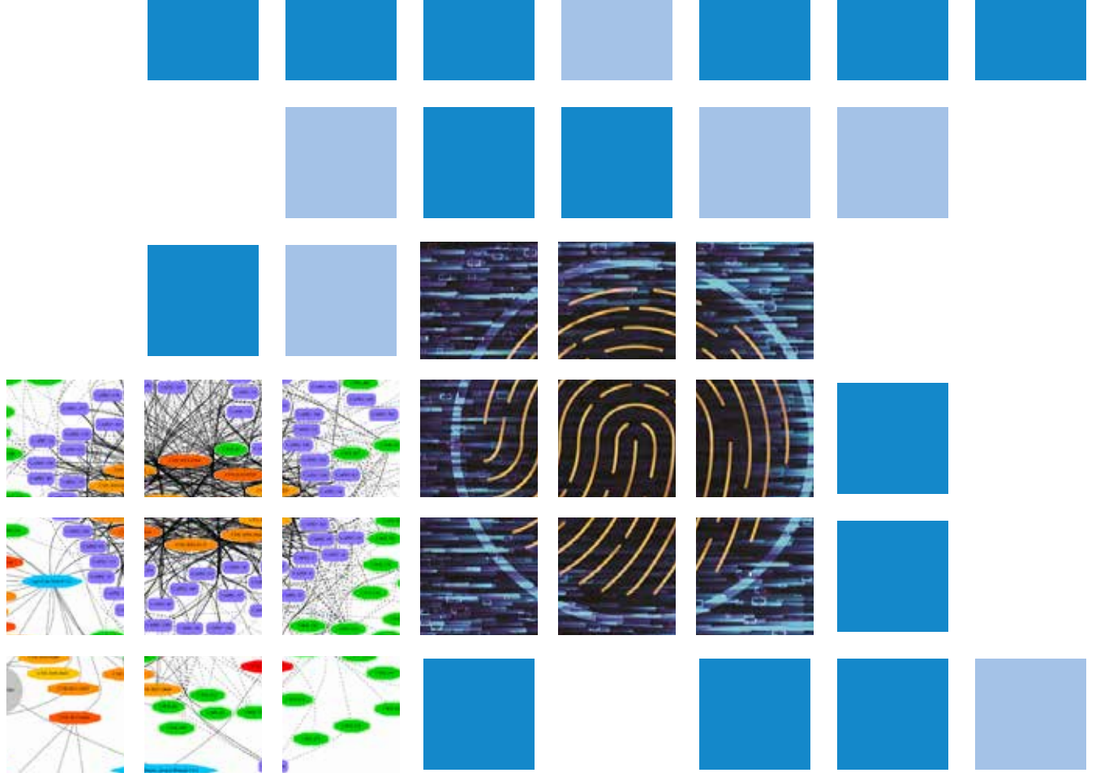
G5269 - Flash Crowds Management via Virtualized Network Resources (FALCON)

Prof. Alberto Leon-Garcia,
University of Toronto, Canada
Prof. Liljana Gavrilovska,
Ss. Cyril and Methodius University in Skopje,
North Macedonia

The FALCON project focuses on dynamic on-demand virtual resource allocation for wireless network environments, leveraging a highly flexible and adaptable wireless network that is able to provide reliable and efficient communications in flash crowd scenarios and emergency situations. In particular, FALCON focuses on developing and designing a novel software-defined and virtualized cloud-based system that provides efficient and reliable communication for emergency situations. The FALCON system aims to support: the operation of various underlying wireless technologies; and the dynamic and optimal allocation of cloud resources (CPU and RAM) to augment the operation of available wireless network resources according to the wireless environment and the traffic demands. The overall system is comprised of Cloud-RAN (C-RAN) and CORE part. This presentation will provide technical insights in the main functional blocks and key features of both parts: the FALCON Cloud-RAN (C-RAN) and FALCON CORE. Specifically, it will discuss the main technologies and solutions behind the proposed C-RAN design, such as used virtualization technologies and optimal virtual resource orchestration. It will also elaborate on the Software-Defined Infrastructure as a key building block of the FALCON's CORE. The presentation will provide specific performance results that showcase the benefits and advantages of the FALCON system in flash crowd scenarios and emergency situations.

G5319 - Threat Predict: From Global Social and Technical Big Data to Cyber Threat Forecast

Dr. Jérôme François,
INRIA, France
Dr. Ghita Mezzour,
International University of Rabat, Morocco
Dr. Kathleen M. Carley,
Carnegie Mellon University, USA



Predicting cyber-attacks can help prevent them or at least reduce their impact. However, few researches on attack prediction make accurate predictions with only hours in advance or they are not able predict geo-politically motivated attacks. The ThreatPredict project, funded by the NATO SPS Programme, aims at predicting different attack types with days in advance. The goal is to develop machine-learning algorithms that capture spatial-temporal dynamics of cyber-attacks and global social, geo-political and technical events. In a nutshell, the project will characterize the relationships between security events and social and geographical related data and, using this knowledge, will finally predict future cybersecurity threats and attacks. We especially aim to improve the research community's understanding of cyber security as a socio-technical problem by analyzing and describing large datasets from multiple sources. To realize this objective, our contribution is three-fold:

- Collection, storage and clustering of both technical and social data within a shared and safe repository
- Correlation of societal and technical data (security related) to highlight their inter-dependency
- Prediction of security threats

G5263 - Analysis, Design and Implementation of an End-to-End 400km QKD Link

Dr. Marina Mondin,
California State University, Los Angeles (CSULA), USA
Dr. Shlomi Arnon,
Ben Gurion University of the Negev (BGU), Israel
Dr. Marco Genovese,
Italian National Institute of Metrological Research (INRIM), Italy
Dr. Inam Bari,
National University of Computer and Emerging Sciences (NUCES-FAST), Pakistan

This project aims at practical implementing a long-range Quantum Key Distribution (QKD) link with trusted nodes, achieving the highest possible secret key rate generation within the security and system level constraints. The project tackles all implementation aspects, from transmission of photon states through an optical fiber or Free Space Optics (FSO) links, to consideration of device imperfections, low and high latency information reconciliation protocols, etc.

In spite of the fact that Discrete Variable QKD (DV-QKD) systems have reached a maturity level that allows their potential full realization and implementation for creation of a secure network backbone for key distribution in nations, in realistic links DV-QKD is really limited by technology and physical constraints associated with construction of reliable high rate single photon (or at least low photon count) sources, and of fast and reliable single photon detectors with very low dark count rates. In these cases, the use of Continuous Variable QKD (CV-QKD) schemes may be advantageous. For this reason the problem of information reconciliation in CV-QKD scenarios is tackled, showing that in long distance links the sign of the received Gaussian samples contains the largest fraction of information, leading to the design of an Unequal Error Protection (UEP) reverse reconciliation scheme. Finally, Forward Error Correction (FEC) codes suitable for both DV-QKD and CV-QKD protocols are investigated, together with their implementation complexity.

G5448 - Quantum-safe Authenticated Group Key Establishment

Prof. Otokar Grošek,
Slovak University of Technology, Slovakia
Dr. Christian Colombo,
University of Malta, Malta
Dr. María Isabel González Vasco,
Universidad Rey Juan Carlos, Spain
Dr. Rainer Steinwandt,
Florida Atlantic University, USA

At this point in time, quantum computing is widely considered more than a mere distant possibility. Substantial resources are currently invested into bringing this technology to the level where it can be commercially used. Unsurprisingly, the implications of large-scale quantum computers on the security of today's communication networks receive a lot of attention at this point: From Shor's seminal work, we know that a large-scale quantum computer has the ability to invalidate assumptions that underlie widely deployed cryptographic solutions and to render these protocols insecure. Several popular cryptographic primitives for digital signatures and key establishment can no longer be considered secure in such a quantum era. With a large-scale quantum computer, secret keys in these protocols can be easily recovered from public data alone.

A particularly prominent effort to address this uncomfortable situation is NIST's ongoing effort to standardize some fundamental post-quantum cryptographic schemes. The process is remarkably complex in that there are no obvious drop-in replacements for currently deployed schemes. Even in the current (Round 2) stage of this effort, there is still quite some movement in the details of the proposed schemes. Our NATO SPS project G5448 already helped to establish a "PQC Wiki," which gives easy access to the current status of the considered candidates.

Overarching goal of this NATO SPS project is to provide a robust solution for (group) key establishment in the quantum era. In other words, we tackle the task that two or more parties want to establish a high-entropy secret over a public, insecure, communication network, and the adversary must be expected to invoke a quantum computer to undermine the security of the protocol. The project's scope includes the design of an authenticated group key establishment protocol and its theoretical analysis, but extends beyond this: to improve resistance against implementation-level attacks, we want to leverage runtime verification. In this way, we can add protections at execution time of a protocol and go beyond what is covered in a standard cryptographic protocol analysis.

G5485 - Secure Quantum Communication Undersea Link

Dr. Alessandro Zavatta,
Consiglio Nazionale delle Ricerche (CNR), Italy
Prof. Andre Xuereb,
University of Malta, Malta
Dr. Davide Calonico,
Istituto Nazionale di Ricerca Metrologica (INRIM), Italy

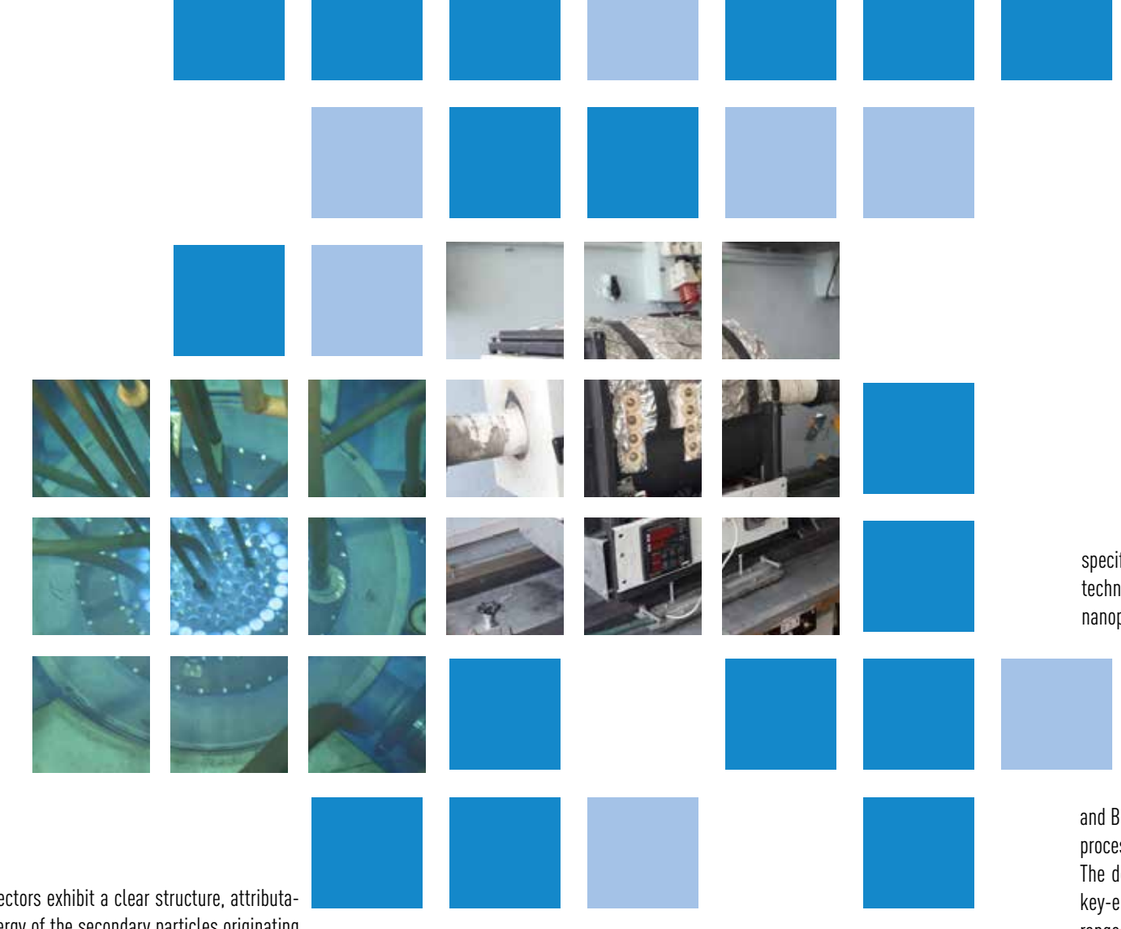
Cryptography aims to establish secure communications between groups of people. It is based on the prior exchange of a key between the communicating parties. Assuming that the key is protected from third parties, messages sent by one party to another can be securely encrypted on one end and decrypted on the other, with no other party being able to access them. The reliability of any cryptographic system is based on efficient and secure key distribution, which remains an important and unsolved issue at the heart of cryptography.

The laws of quantum mechanics can be used to create an unconditionally secure quantum key distribution (QKD) protocol. QKD promises to a leap forward. It promises to achieve unconditional security in communications, guaranteed by the laws of the universe as opposed to the rules of computational complexity. Because of this, QKD is currently considered the only technology able to guarantee an absolutely secure solution for the key exchange problem. Experimental realizations of QKD in several laboratories have advanced significantly over the past two decades. Today, QKD systems have started to be transferred to real-world environments for practical use. However, in order to become a practical solution for high-level security applications, QKD hardware needs to guarantee long-term stability as well as the reliability of the security it offers. Imperfections in the transmission channels and detectors, for example, open so-called side-channels that in principle could allow the leakage of some key information to an eavesdropper.

The scope of this project between Italy and Malta is to realize the first undersea quantum key distribution link between two different countries on this scale. This quantum link will be set up over an existing submarine fiber link, covering a distance of about 100 km, between Malta and Sicily. One of optical fibers that connect Malta to Sicily was very recently used to demonstrate that the ephemeral entangled state of two photons survives when one of them is sent on a journey from Malta to Sicily. The natural next step is to implement a QKD platform over a similar link.

G5215 - Engineering Silicon Carbide for Enhanced Border and Port Security (E-SiCure)

Dr. Ivana Capan,
Rudjer Boskovic Institute, Croatia
Dr. Željko Pastuović,
Australian Nuclear Science and Technology Organisation (ANSTO), Australia
Dr. José Coutinho,
University of Aveiro, Portugal
Dr. Takeshi Ohshima,
National Institutes for Quantum and Radiological Science and Technology (QST), Japan
Dr. Luka Snoj,
Jozef Stefan Institute (JSI), Slovenia



In 2016, the SPS funded research project "Engineering Silicon Carbide for Border and Port Security" - E-SiCure was launched, its objective being the development of radiation-hard silicon carbide (SiC) based detectors of special nuclear materials (SNM), with the aim to enhance border and port security barriers. Detector prototypes based on SiC Schottky Barrier Diodes (SBDs) and neutron converter films were developed. This paper presents the results of a dedicated experimental testing campaign performed at the Jozef Stefan Institute (JSI) TRIGA reactor in which several SiC detector prototypes equipped with ^{10}B and ^{6}LiF converter films were irradiated in the Dry Chamber of the reactor. The obtained results demonstrate a clearly measurable neutron response, which varies linearly with the neutron flux. The measured particle spectra with the SiC detectors exhibit a clear structure, attributable to the nature and energy of the secondary particles originating as reaction products from nuclear reactions on the isotopes ^{10}B and ^{6}Li. The determined sensitivity of the detectors, their active volume being 1 mm × 1 mm × 25 µm, 1 × 1 mm × 69 µm and × 1 mm × 170 µm, was on average around 1.2×10^{-5} counts per second, per unit of neutron flux [counts s^{-1} / n cm^{-2} s^{-1}]. In practical applications, an array of such detectors of e.g. 100 × 1000 (the dimensions being around 20 cm × 2 m) would allow a sensitivity of around 1 count s^{-1} / n cm^{-2} s^{-1}, which is already comparable to typical neutron sensitivity values, in the range from several to over 100 counts s^{-1} / n cm^{-2} s^{-1}.

G5120 - Infrared Transparent Ceramic Windows for High-speed Vehicles

Dr. Mathias Hermann,
Fraunhofer Institute of Ceramic Technologies and Systems, Germany
Prof. Andrey Ragulya,
National Technical University of Ukraine, Ukraine

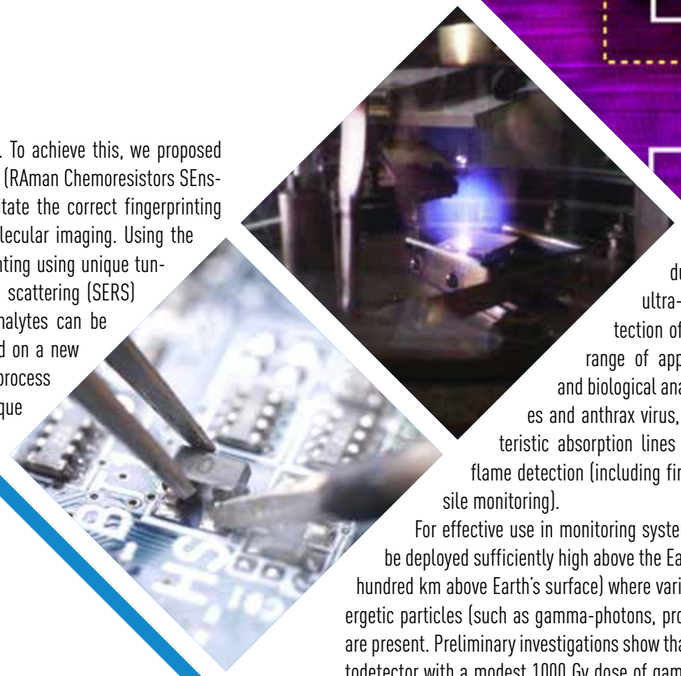
The project has created new technical approaches to manufacture large size transparent ceramic windows (transparency 85% and higher in the IR part of spectrum) using advanced consolidation techniques such as 3D printing (binder jet printing of green prototypes up to 120 mm in diameter) and spark plasma sintering (enable to form domes of 70 mm in diameter).
The proposed approach has required the development of ceramic nanopowders specifically formulated by internal structure to be applied in 3D binder-jet technology of meniscus-shape domes. The technologies for the synthesis of nanopowders of magnesium fluoride and magnesium-aluminum spinel have been developed, and batches of 3 kilograms of the both powders have been manufactured. According to the results of the analysis, it was found that the powders are thermally, mechanically and optically-suitable for the manufacture of IR-transparent windows.
Shaping technologies by slip casting and 3D-printing suitable for sintering under pressure have been developed. Granules from KPI powders and Baikovsky powders have been prepared. Based on the granules a printing process have been developed using CJP 360 printer.
The developed technologies of spark-plasma sintering and hot pressing are key-enable technologies to produce transparent (88% and above) in the IR range. It has been shown that rapid sintering conditions and variable pressure application can achieve high values of density and optical transparency and avoid excessive grain growth. Studies of the properties of manufactured samples of IR-windows have demonstrated the feasibility of the proposed technological approaches (spark-plasma sintering or hot pressing) for the pilot production of dense homogeneous ceramics from magnesium fluoride and magnesium-aluminum spinel with a fairly high level of transparency (higher than 88-91 %) in the infrared diapason. Specific design of this graphite instrument was helpful to manufacture optically transparent domes with uniform transparency up to 91 %.

G5140 - Advanced Nanotechnologies For Multivariate Sensor Fabrication

Dr. Andrea Goldoni,
Elettra - Sincrotrone Trieste, Italy
Dr Borys Snopok,
V.Ye. Lashkarjov Institute of Semiconductor Physics National Academy of Science of Ukraine, Ukraine
Dr. Alberto Verdini,
Istituto Officina dei Materiali, Consiglio Nazionale delle Ricerche (CNR), Italy

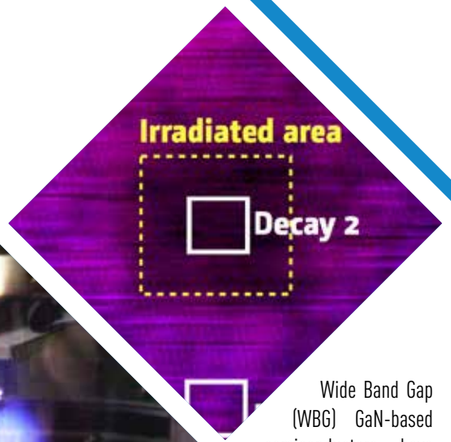
The rapid identification of chemical or biological agents associated with any incident involving hazardous materials is vital for the effective management of the consequences and the rescue of casualties. A wide range of commercially available detection equipment is available, including monitors developed by the military. However, traditional military approaches are not necessarily suitable or easily adaptable for use by civilian security services dealing with a heterogeneous group of victims in peaceful conditions. Moreover, since a xenobiotic "attack" of any kind (for example, a terrorist act, as well as environmental pollution or food poisoning) is a very low probability event, the ultimate goal of equipment for identifying chemical / biochemical agents is fast (i) and inexpensive (ii) detect the presence of potent xenobiotics (iii) in the field using a portable (iv) device and transmit information (v) using standard protocols for data analysis and make a decision. However, a potential complication that can easily be overlooked is that a potential "attack" of xenobiotics may involve the use of an a priori unknown or more than one toxic agent — thus, several different analyzes must be processed simultaneously.

The main goal of the ANT project was to develop a set of advanced technologies with an integrated intelligent decision support system that would locally detect, identify and characterize organic CBRN embedded in complex matrices in a fast, accurate and reproducible way. To achieve this, we proposed developing a virtual array based on RACHSEPT (RAman Chemoresistors SEnsing PlaTform), where chemical sensors facilitate the correct fingerprinting of organic xenobiotics using SERS-based molecular imaging. Using the multidimensional concept of virtual fingerprinting using unique tunable substrates for surface enhanced Raman scattering (SERS) and advanced chemical sensors, multiple analytes can be detected simultaneously. The project is based on a new version of the pulsed laser deposition (PLD) process using backflow technology (bw-PLD) - a unique and cost-effective process for manufacturing functional porous nanocomposites with desired properties.



G5453 - Radiation Hard UV Detectors against Terrorist Threats

Dr. Leonid Chernyak,
University of Central Florida, USA
Dr. Igor Lubomirsky,
Weizmann Institute of Science, Israel
Mr. Sergey Khodorov,
Weizmann Institute of Science, Israel



Wide Band Gap (WBG) GaN-based semiconductors have gained increased attention due to their ability to detect ultra-violet (UV) radiation. The detection of UV radiation presents a wide range of applications, such as, chemical and biological analysis (most organic substances and anthrax virus, for instance, present characteristic absorption lines in the UV spectral range) or flame detection (including fire alarms, combustion or missile monitoring).

For effective use in monitoring systems, UV photodetectors should be deployed sufficiently high above the Earth, i.e., on a satellite (several hundred km above Earth's surface) where various types of radiation and energetic particles (such as gamma-photons, protons and energetic electrons) are present. Preliminary investigations show that irradiation of GaN p-i-n photodetector with a modest 1000 Gy dose of gamma-rays results in significant deterioration of spectral photoresponse characteristics. This deterioration may lead to faulty detection and, therefore, presents a serious device reliability issue. Note that radiation shielding significantly increases satellite's weight and may be a source of secondary radiation.

The transport properties of minority carriers are an important indicator for the quality of Wide Band Gap semiconductors, as well as a critical factor determining performance of bipolar semiconductor devices, in particular, photovoltaic detectors. One of the main difficulties that must be overcome in GaN and related materials, is a reduced minority carrier diffusion length, L. Enhancement of L presents a serious technological challenge, since this cannot simply be achieved by the growth of low defect level material. Limitations, especially in heteroepitaxy, arise from the lattice mismatch between III-N epitaxial layer and the underlying substrate (sapphire, for example). To obtain a pronounced increase of L merely by reduction of carrier scattering on the dislocation walls, the threading dislocation density must be brought down to at least 107 cm-2 from the typical levels of 108-109 cm-2.

It has been found that electron injection into p-type GaN leads to considerable changes in the material's electronic properties, in particular longer diffusion length, which translates into up to one order of magnitude enhancement of a photovoltaic detector response, thus indicating a possibility of device performance control. It is, therefore, possible to improve performance of photodetectors, affected by radiation, using short (seconds or less) solid-state forward-bias electron injection in GaN p-i-n devices. This injection will result in enhanced L in the top p-type absorption layer of a photodetector, thus increasing the quantum efficiency for the device and "healing" the adverse impact of gamma-rays, protons, electrons and other radiation types.

G5580 - Creation of New Generation Titanium Diboride Composite Armour Material

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The next generation Armour Piercing Bullet with Tungsten Carbide core has been introduced into the world's leading military forces by the beginning of the 21st century, resulting in a sharp increase in penetrability of the existing standard composite armour plates. The only armour system that effectively stops these bullets is a combined structure obtained through a hot-pressing technology and composed of multilayer fabric made of high-molecular organic fibres. Despite the high armour properties of the above-mentioned structure, its components (separately and together) have some negative sides as well: high cost, low production capacity and low firmness of armour ceramics, which hinders its widespread use in personal protective equipment and in armoured combat vehicles as well. Therefore, there was a need to find new approaches in processing technologies of protective structure and its new components in order to create a new generation armour material for ceramic armour characterized by high hardness and strength (not less than boron carbide), low cost and high capacity and with the following physical-mechanical properties: micro hardness - 3600-3800 kg/mm2; bending strength 70-80 kg/mm2; density - 4.0–4.5 g/cm3. The obtained results will allow us to replace the boron carbide ceramics with a relatively inexpensive and perspective armour material.

With regard to the second element of armour structure, a new approach has also been found to composition of multilayer fabric and manufacturing technology, which involves the production of a high performance industrial thermo-hydro forming unit, which in liquid, under high pressure and temperature, would thermoform composite armour products (ballistic ceramic plate) of complex configurations. This method gives us the opportunity to get a composition of thermally pressed multilayer fabric (ceramic plate) composed of relatively cheap, impact-resistant and puncture-resistant super-hard materials.

Based on the above mentioned, we expect to obtain the new generation armour plates characterized with high-quality protection, low cost and high capacity of production through combining two different components of armour with enhanced properties into one composition. This will allow their widespread use in personal protective equipment and in all kinds of armoured combat vehicles as well.

G5030 - Titanium Armour with Gradient Structure: Advanced Technology for Fabrication

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The anti-ballistic protection of land systems, mobility and protection of the fighting vehicles and military personnel is vital in success of defense and anti-terrorist operations. Traditional material for armor is rolled homogeneous or high strength steel. Use of steel armor, however, can increase the overall weight of the fighting vehicle on 15-20%, which change the vehicle mobility, maneuverability, fuel efficiency and requires stronger breaks and more powerful engines. Defence and security forces are in search of lightweight substitute for steel armor. Due to the high specific strength of titanium, materials on its base are contemplated as a viable alternative in low-weight armor production. However, when the armor parts are fabricated using traditional cast and wrought technology the feasibility of implementation is questionable due to the high cost of the armor parts. In this regard the use of blended elemental powder metallurgy (BEPM) instead of ingot metallurgy of Ti offers an effective cost reduction due to its ability to produce near-net shape parts, while the waste is considerably reduced. Additionally, the price of BEPM fabricated components can be reduced through the use of low-cost hydrogenated titanium powder instead of conventionally used in powder metallurgy (PM) high-cost titanium metal powder. One of the key benefit of BEPM is that such fabrication can easily facilitate reinforcement of Ti-alloys with hard and light particles, for instance of TiC and TiB making metal matrix composites (MMC) with enhanced elastic moduli without compromising the material's low-weight so desirable for armor. Reinforcement of the alloy with hard particles, however, most likely lowers the value of toughness and plasticity of material. Yet, for durable armor, simultaneous high hardness and high plasticity are not essential through the entire structure: armor parts require high hardness and strength at the surface, whereas their core rather necessitates high toughness and ductility. Such blend of mechanical properties can be achieved on layered structures that combine two and more layers of different materials with different chemical composition and/or microstructure within each individual layer. The objective of this study is the development of cost-efficient technology for fabrication of low-weight and superb anti-ballistic properties multilayered (ML) structures made using BEPM of Ti alloy and composites on its base with TiB and TiC.

G5267 - Maritime Security - Multistatic and Multiband Coherent Radar Fleet for Border Security (SOLE)

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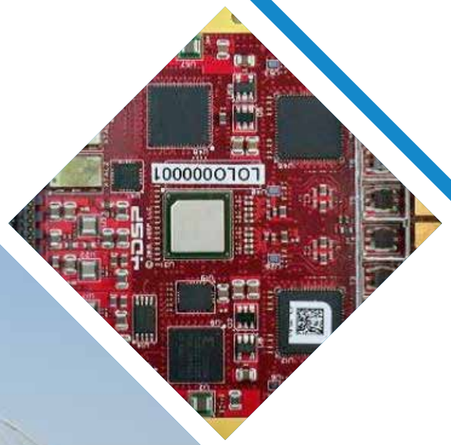
The "multiStatic & multiband cOherent radar fLeet for border sEcurity" (SOLE) project aims at the realization of a demonstrator of a full-functional radar network based on the coherent multi-static approach, leveraging on the intrinsic high level of coherence of photonics. Indeed, the proposed remote sensing network employs photonics for the local oscillator generation inside a central unit (CU) and for the radar peripherals (RPs) remoting, exploiting radio-over-fibre (RoF) techniques. Moreover, the proposed distributed radar system benefits from the multiple input-multiple output (MIMO) approach, enhancing the cross-range resolution allowed by the antenna aperture, and enabling the possibility of implementing high-performance imaging algorithms. To this aim, suitable data processing techniques are considered, as well as algorithms for multistatic inverse synthetic aperture radar (ISAR) and interferometric sensing applications, to obtain a radar system with enhanced sensitivity and precision. Here, we report on the experimental activities that spanned over several months, for a first validation of the architecture of the proposed system and the related processing. In a campaign of in-field measurements, we tested a down-scaled version of the photonic, multistatic coherent radar network, with 2 transmitters (TXs) and 2 receivers (RXs). In a first set of measurements, some airplanes passing in the proximity of the test field have been detected, to evaluate the suitability of the proposed architecture applied to ISAR imaging. In the second, two closely-spaced moving targets were employed, carried by two drones, applying MIMO processing to enhance the cross-range resolution. In both cases, the benefits of the inherent coherence brought about by photonics have been demonstrated.



G5465 - Noise Imaging Radar Network for Covert Air and Maritime Border Security (NORMA)

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Given the nature of current evolving threats, border security has become of paramount importance both in civilian and military application. In particular, both air and maritime borders are threatened by unlawful activities which employ new technologies and require the use of more effective surveillance sensors. For example, unmanned platforms employed by drug smugglers require the intervention of border authorities with more effective systems, which allow an efficient and continuous monitoring of land and sea borders. In particular, such solution should face both civilian and military issues, allowing for all weather/all day operations and covert/LPI (Low probability of Intercept) capabilities. The proposed solution in this project is a radar network system composed of cooperating wideband noise imaging radars. The capability of the radar to be operative all weather all day 24 hour per day accomplished with the main characteristic of transmitting noise and/or noise-like wideband waveforms with imaging capability is a powerful solution to have an LPI land and sea border surveillance also in critical and sensible regions that are difficult to be monitored by human patrolling missions. It is worth pointing out that LPI is a desired feature especially for military applications that have to deal with antagonistic and hostile forces trying to prevent the surveillance of specific and sensitive areas. The radar is also designed to have an RCS mode for the measurement of target reflectivity and 1D-2D imaging capability, including also detection and tracking techniques for the revelation of slow target motions in sea and strong land clutter, which is a very important function for sea border surveillance and mainly for low flying drone detection.

G5248 - Compact Eye-Safe Lidar Source for Airborne Laser Scanning (CALIBER)

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The security and protection of borders, infrastructures and strategic sites, such as gas and oil platforms, maritime infrastructures and power plants, is of paramount importance. Continuous monitoring of these areas can be performed by using light and compact devices that can be placed on Unmanned Aerial Vehicles (UAVs) or in specific locations of the premises where a small footprint equipment is required. Light Detection and Ranging (LIDAR) systems offer a powerful remote sensing technique, which uses laser light to retrieve information about the environment and surroundings close to its location. The light emitter is a key element of the system and contributes to the overall system performance. The quality of the sensing strongly depends on the type of source employed, in terms of wavelength, pulse width, average and peak power, which altogether define the precision and reliability of the overall system. A flexible and advantageous approach to realize a high-power LIDAR source is the Master Oscillator Power Amplifier (MOPA) configuration. A seed laser with high spectral quality is followed by a single- or multi-stage power amplifier that boosts the output power to attain the needed energy.

The CALIBER project aims to develop a compact, lightweight and low-cost version of a LIDAR source, by integrating a Semiconductor Saturable Absorber Mirror (SESAM) Q-switched microchip seed laser and a new Er:Yb power amplifier in a compact MOPA configuration, which combines high repetition rate and high peak power at the "eye-safe" wavelength of 1535 nm.

G4840 - Microelectronic 3D Imaging and Neuromorphic Recognition for Autonomous UAVs

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An international team of researchers have been developing highly sensitive, low-light and efficient, miniature single-photon sensor technology based on Single Photon Avalanche Diode (SPAD) arrays. A key motivation was to use Silicon CMOS-based processes and advanced 3D-IC manufacturing technologies to miniaturize arrays and digital circuits to realize affordable high definition imaging microchip sensors. Imaging cameras using smart photon sensor SPAD microchips are integral to active Electro-Optic systems such as 3-D Flash -Light Detection and Ranging (LiDAR) for target detection and identification and tactical applications requiring imaging in very low light conditions. When coupled with sophisticated machine learning algorithms the work demonstrated accurate detection and classification of land-based targets from a low cost Unmanned Aerial System (UAS).

3-D Flash LiDAR systems, also known as 3-D Time of Flight (ToF) cameras which use 'SPAD array' sensor technology have some advantages over existing LiDAR scanning methods. They have no moving mechanical parts and scanning optics; hence they acquire a 3D depth-resolved image of a scene instantaneously allowing faster image reconstruction and is especially useful when targets are moving or when large areas need to be surveyed quickly. They also offer an improved SWaP (Size Weight & Power) footprint over scanning systems, which means they can fit easily on power starved and mobile platforms such as UASs. By interfacing SPAD based sensor technology with machine learning image processing techniques (in this work neuromorphic-like algorithms were implemented), it is then possible to perform classification of imaged targets in real time, with improved target detection and recognition performance. In this work over 98% detection accuracy was demonstrated.

The project was able to develop new state of the art SPAD sensors, was able to successfully integrate and fly a low SWaP Flash LiDAR system on a custom built multi-rotor UAS platform, collect real time imagery and perform neuromorphic processing for accurate target detection and classification.

G5437 - Wide InTegration of sensor Networks to Enable Smart Surveillance (WITNESS)

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In the recent years the need of advanced security systems has grown in un unpredictable manner. We saw how modern cities are very susceptible to terrorist attacks and the population asks to feel safer. In this perspective WITNESS project was designed to help security forces to prevent terrorist attacks and to facilitate disaster recovery scenarios. In this project we break down some aspects of modern surveillance systems, providing a system architecture and methodology, as well as several use case scenarios which WITNESS will cater for. The overall goal of the project is to implement an advanced framework for urban surveillance and security to enable the detection, characterization and efficient response to terrorist threats and attacks. WITNESS exploits state-of-the-art sensor fusion technology to develop innovative methodologies, algorithms and tools to improve the situational awareness and threat detection in urban unpredictable scenarios.

G5244 - Graphene / Polymer based Sensor

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The atmospheric pollution with toxic gases is considered as serious environmental problem in human society. Toxic gases like CO, NH3 and NO2 are one of the most common air pollutants that can irritate skin, corroded lung tissue and respiratory tract and in the worst case, cause mortal danger, especially in case of continuous exposure. Awareness of the presence of these toxic gases is of extreme importance; consequently, development of gas sensors with high performance is required.

Offering new materials for gas sensing performance with low cost, simple preparation, high sensitivity, selectivity and reproducibility at ambient working conditions are the main objectives of this project. Using relatively low cost, water-borne polymer system with excellent physical and chemical properties reinforced with different carbon based nanomaterials was considered as the most appropriate. The polymer matrix consisted of copolymer made of methyl methacrylate and butyl acrylate, synthesized by polymerization in dispersed media techniques, such as emulsion or mini-emulsion polymerization. The polymer particles obtained are usually functionalized using small amount of functional monomers, such as glycidyl methacrylate or acrylamide or acrylic acid, which improve compatibility with the filler. Additionally, to improve the distribution of the filler within the polymer matrix and sensing properties of the composite materials, post-treatment by laser ablation is performed.

G5351 - Nanocomposites Based Photonic Crystal Sensors of Biological and Chemical Agents

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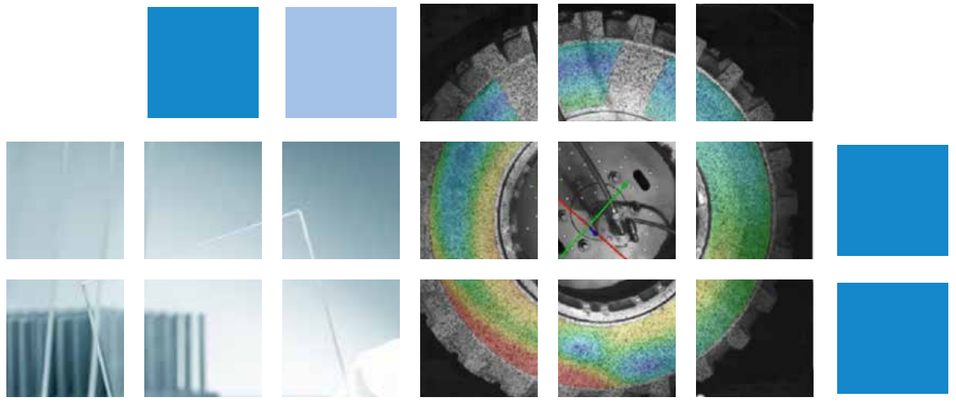
Lviv Polytechnic National University, Ukraine

Waveguide photonic crystal (PC) structures possess the anomalous resonant phenomena termed guided-mode resonance, which manifests itself as a series of strong peaks in reflection (transmission) spectrum of the structure. The central wavelengths of these peaks can be changed by varying the PC structure parameters and environment permittivity. Such PC structures can be used for sensing of chemical and biological analytes deposited on the PC surface by monitoring the resonance wavelength shift. In addition, phase-matching of the wave diffracted by the periodic structure with the eigenmode of waveguide under resonance conditions results in the strong enhancement of the field in the waveguide as well as in the vicinity of its surface (a local field). Thus, the excitation of local field fitting the analyte absorption or/and emission spectra can promote high enhancement of fluorescence and Raman scattering of analytes (an enhancement effect).

Nowadays, the main considered candidates for polymer based sensors are 1D, 2D relief structures fabricated by the techniques adopted from the microelectronics. As an alternative, we proposed to develop the resonant waveguide PC structures with volume periodic modulation of permittivity and flat surface, which can be fabricated using photosensitive polymer-based nanocomposites containing inorganic nanoparticles (NPs) of different nature. This approach possesses a number of advantages. Volume structures can be fabricated by a one-step holographic lithography method that enables the production of large-size PC structures with excellent homogeneity and easily varied symmetry and period. The permittivity (refractive index) modulation of these materials is achieved due to redistribution of the nanocomposite components during holographic patterning. The structures with a flat surface do not mechanically alter the deposited biological objects thus keeping their fluorescent properties intact. All these opens perspectives to increase the sensitivity of sensors based on volume PC structures.

The goals of our work are (i) the computer design of the PC structures, prediction of their characteristics; (ii) fabrication of PC structure prototypes with optimal grating-waveguide parameters (thickness, period, amplitude of refractive index modulation) theoretically calculated for sensing applications; (iii) research of the resonant properties of PC structures; (iv) investigation of the label-free sensor based on the nanocomposite PC waveguide structure.



G5176 - Agile Tyre Mobility for Severe Terrain Environments

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Dr. Lyubomyr Demkiv,
Lviv Polytechnic National University, Ukraine

The project aims to develop, implement, and test a new technology for military vehicles that would improve the off-road mobility by providing agile (fast, exact and pre-emptive) responses and advanced mobility controls in severe terrain conditions. Additionally, the project tackles the protection of vehicle's electronic and software components from cyber-attacks. The military vehicle mobility, safety and survivability would be improved by the added potential of a vehicle for a rapid change in acceleration or speed or its ability to improve its towing capacity.

The system would be capable to sense tyre mobility faster than currently possible and provide an agile control action to maintain high-level mobility in severe terrain conditions for military vehicles. The proposed vehicle technology will also develop a cyber-protection system for the tyre mobility computer code, controller and communication information that could also be used in unmanned/autonomous ground military vehicles.

G5293 - Autonomous Platform for Securing Marine Infrastructures

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IMDEA Networks Institute, Spain
Dr. Roee Diamant,
University of Haifa, Israel
Dr. Lutz Lampe,
University of British Columbia, Canada

The ThreatDetect project proposes a novel design for the autonomous detection of divers and submerged mines, including the development of a prototype for the demonstration of the system's capabilities. The project targets the security of marine infrastructures like gas rigs and harbor entrances. Considering the challenge and risks represented by intruders and explosive ordnance for such sensitive underwater infrastructure, ThreatDetect employs a combination of active acoustic detection for the identification of scuba divers, and sonar target detection for the threat of submerged mines. In order to achieve a quickly deployable and cost-effective system, the diver detection is performed via a single active acoustic transceiver deployed from a surface buoy or a small vessel and involves both the detection and the localization of the threat. Then, to handle the threat of submerged mines, an autonomous underwater vehicle (AUV) surveys the area and automatically detects mine-like objects. The sonar image is then transmitted to a surface station via underwater acoustic communications.

Relying on the broad experience of its team members, ThreatDetect involves techniques from signal processing, image processing, control theory, and telecommunications. Our novel design was required in order to overcome challenges such as: strong reverberation when detecting a small target in shallow water; multipath reflections that distorts the received signals and harden localization, and interference from shipping activity when transferring the sonar image from the AUV to shore. The developed techniques were tested in more than 20 sea experiments in the Mediterranean sea involving both real scuba divers and mine-like objects surveyed by an AUV and surface vessels, mimicking the application scenario. This effort has led to 13 journal and 11 conference publications and over the first two years of the project.

G5322 - High Altitude Balloon-Borne Radar

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Reconnaissance, surveillance and information gathering is an essential part of maintaining security and significant effort is spent on systems to enable these functions. Current technologies, which mainly employ satellites, aircraft (both manned and unmanned), and drones suffer from a number of shortcomings. Space-borne systems operate from a large distance and, provided careful constellation design, are able to cover almost all areas on the surface of the earth. However, space missions depend on the presence of a satellite over the designated area which can only happen at particular times that are determined by the orbit. Also, they do not offer a rapid and timely response as the ability to repeat measurements over a given area is constrained by the satellite orbit, which may impose intervals of several hours or even days between revisits. Airborne systems operate at much lower altitudes and Manned aircraft missions put pilots' lives at risk being inherently vulnerable to attacks. Their size, and therefore Radar Cross Section, and flight altitude limits make them easier to detect. UAVs take the pilot out of the equation, they still suffer from all of the other problems associated with manned aircraft including cost and vulnerability.

High altitude platforms (HAPs) have also been proposed for the gathering of surveillance data. These platforms complement aircraft and satellites and enjoy a number of unique advantages with respect to both alternatives. HAPs operate at altitudes exceeding 20km, and include certain aircraft, airships and balloons. Their high altitude gives them a higher degree of immunity against attack as compared to aircraft while providing them a wider field of view. On the other hand, they are a cheaper alternative to traditional satellite systems as their development and deployment costs are much lower than those of a spacecraft. Their comparatively low altitude, with respect to spacecraft, makes them more versatile and recoverable meaning that they can be maintained and even upgraded.

The project proposes a new high-altitude balloon-borne synthetic aperture radar (BALSAR) system that overcomes the shortcomings of existing systems without compromising performance, such as resolution, signal-to-noise ratio and hence target detection and recognition. The new system has a number of significant advantages over the aforementioned solutions. It is very low cost and hence expendable, rapidly deployable, has low probability of intercept (LPI) characteristics.

G5428 - Dynamic Architecture based on UAVs Monitoring for Border Security and Safety

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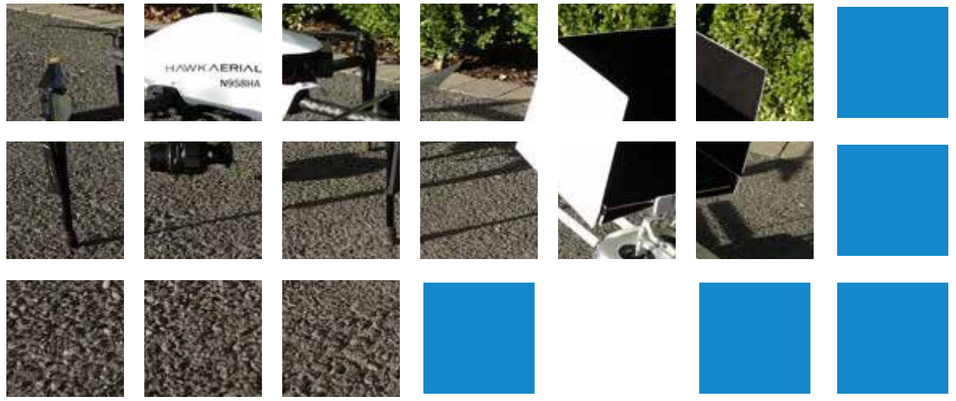
Università di Trento (UNITN), Italy
Prof. Reuven Cohen,
Technion, Israel



With the advent of 5G, networks are expected to include an unprecedented functionality: fast deployment. Indeed, 5G requirements include the possibility of deploying a functional next-generation wireless networks in less than 90 minutes, where for LTE this would have required days. Such requirement would require the usage of a software-based and configurable network architecture as well as the availability of proper network nodes capable of moving in the territory. The 5G Service Based Architecture defined in 2019 provides an important step forward on the softwarization of the telco infrastructure by enabling the deployment and orchestration of Virtual Network Functions on the network infrastructure. On the other hand, Unmanned Aerial Vehicles have recently gained the attention of the communication community as a potential technology to deploy movable and agile network nodes for fast deployment of network nodes. NATO SPS G5428 DAVOSS project focuses on merging those two concepts (5G SBA and UAVs) to build a communication and service architecture capable of providing coverage for monitoring, border security and safety applications. Indeed, DAVOSS project aims to develop a multi-layer virtualized system in which all the technologies listed above work together to guarantee efficient and effective borders and ports surveillance.

G5568 - Mobile Adaptive/Reactive Counter Unmanned Aerial System (MARCUS)

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Dr. Markus Höpflinger,
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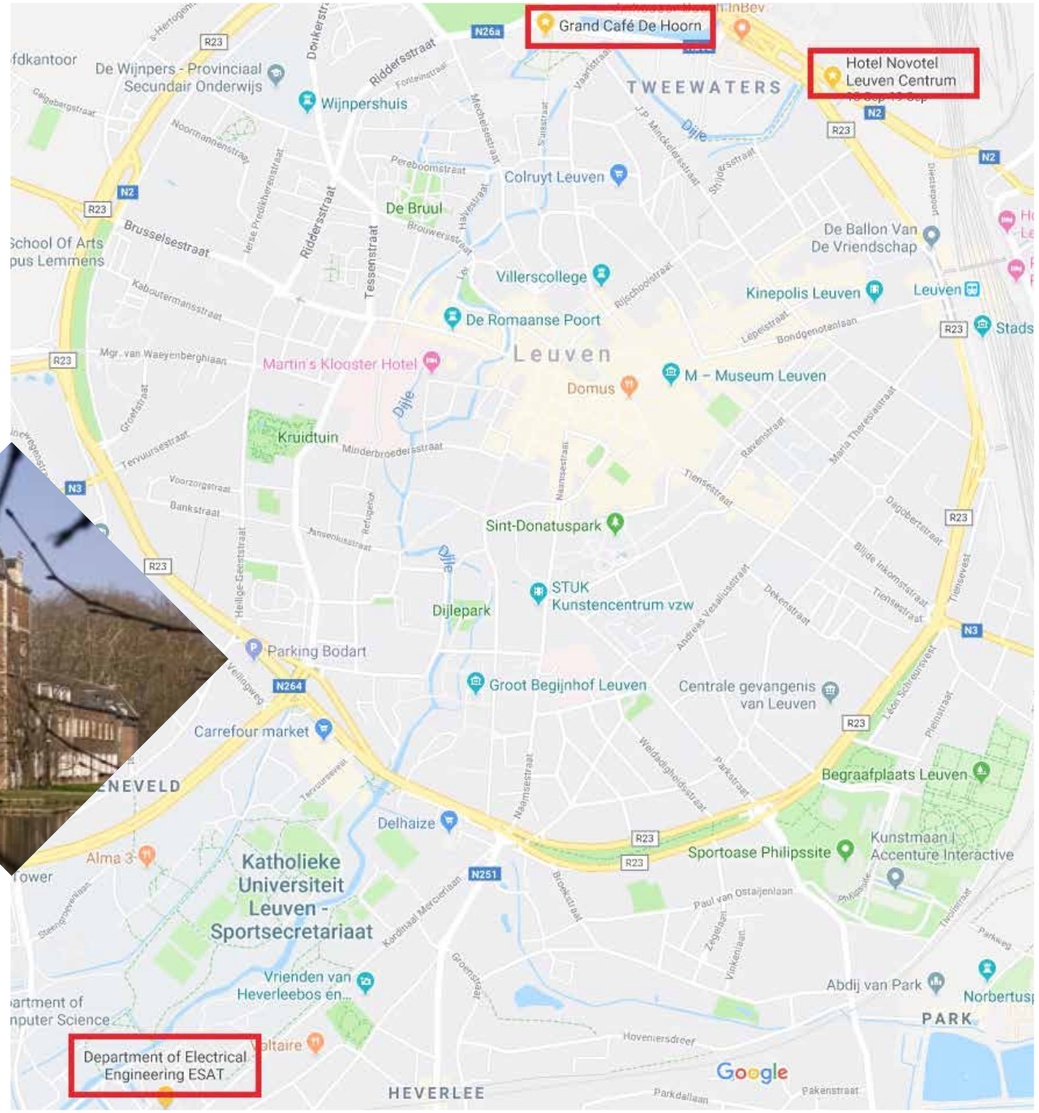
University of New Mexico, USA

The Mobile Adaptive/Reactive Counter Unmanned Aerial System (MARCUS) project aims to develop technology to address current and future low-slow-small (LSS) threats to national security posed by un-manned aerial systems (UAS). The project will make use of both airborne and stationary/mobile ground-based sensors to increase situational awareness (with respect to the target and collateral damage to the environment) and to efficiently neutralise LSS threats.
The MARCUS Project develops counter-UAS capability in three key areas: (i) detection and identification of a potential LSS threat, (ii) tracking and assessment, and (iii) neutralization of the UAS threat. These elements will enable a mobile, adaptive, and responsive cUAS technology to respond to the growing threat.

KU Leuven and its Department of Electrical Engineering (ESAT)

KU LEUVEN

KU Leuven will celebrate its 600th anniversary in 2025, making it one of Europe's oldest universities.
Today, KU Leuven accommodates 50,000 students, spread across the various campuses in Leuven and elsewhere in Flanders. The University and University Hospitals Leuven each employ almost 10,000 people. For research, KU Leuven ranks among the world's finest. KU Leuven has become a cosmopolitan institution in a rapidly changing urban environment. Its unique profile reconciles cutting-edge science with quality of life and openness to talent.
The department of Electrical Engineering (also known as ESAT) of the KU Leuven conducts research at a high international level. It is also responsible for education in the domains of electrical engineering, electronics, and information processing. ESAT works on several technological innovations in the fields of energy, integrated circuits, information processing, image & speech processing, and telecommunication systems. The department is also co-founder of many spin-off companies. With more than 300 PhD students, 200 master students, and 100 staff members, ESAT is a strong international research and educational department.



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