AFRL

AIR FORCE OFFICE OF
SCIENTIFIC RESEARCH

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AFRL/AFOSR
International Office
FY21 Annual Report

ION	IOAM	IOE	IOA	IOS	IOSB
ARLINGTON, VA	MELBOURNE, AUSTRALIA	LONDON, UK	TOKYO, JAPAN	SANTIAGO, CHILE	SAO PAULO, BRAZIL

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Letter from the IO Director

Dear International S&T Partners and Stakeholders,

Upon joining AFOSR's international science division this year, I was excited by the accomplishments of such a small organization. It was inspiring to watch the entire team as they pursued opportunities to provide the Department of the Air Force awareness of, engagement with, and relationships to overseas basic research. Additionally, our principle investigators continue to prove their skill at teasing out extraordinary scientific results, several of which are introduced in this report.

Despite the limitations imposed by COVID-19 on our international program officers (IPOs), they continue to curate and guide research portfolios that are breaking down the scientific barriers to novel defense capabilities. While we have learned to conduct a significant amount of our work virtually, much of the scientific progress and opportunities are most effectively understood through direct interaction. To that end, we completed 57 visits to 27 different countries across 66 institutions. Additionally, we conducted 108 assessments of new and continuing research. These visits and assessments formed the basis of our continued progress in basic research.

In September, we were pleased to host the Department of the Air Force's Chief Scientist, Dr. Victoria Coleman. Dr. Coleman had the opportunity to visit EOARD at the Imperial College I-HUB and learn about select DoD international research efforts across the Army's Combat Capabilities Development Command, the Navy's Office of Naval Research – Global, and AFOSR's International Science Division. This visit highlighted the long-term, strategic importance of basic science to the Department of the Air Force.

We continue to support five global initiatives, partnering with Israel (materials science), Malaysia (hypersonic flow and biomarkers), Australia (autonomy), Korea (nanomaterials), and Taiwan (space and quantum). These partnerships help us connect researchers around the globe to top experts in the United States. In particular, the Korean and Taiwan initiatives started new phases this year. As our longest running initiatives, they have helped us form enduring relationships over the past 20 years. For the next three years, the Taiwan Initiative will focus on *Topological and Nanostructured Materials Synthesis and Discovery*. The Korean Initiative is expanding from its historical focus on nano-structured materials to two major areas of growth: Space and Quantum Sciences.

Of course, we owe these programs and successes to the hard work of the personnel supporting the International Science Division. This year, we said goodbye to the AFOSR/IO Director, Col DBrent Morris, who retired from the Air Force after 31 years of dedicated service. Col Morris led the division through significant change, initiating new international operating locations in Australia and Brazil while caring for his personnel and advancing the mission during the COVID-19 outbreak. Furthermore, EOARD saw the departure of Lt Col David Garner, Lt Col Shad Reed, Mr. Anthony Vaughn, Ms. Victoria Madison, and Ms. Emily Bannon. Mr. Kevin Bannan transferred from IOE to ION and is now supporting division-level budget planning and execution. Our Tokyo office said goodbye to both Maj Chris Vergien and Ms. Patricia Gorski. Dr. Geoff Andersen left our Santiago office to serve a 6-month rotation as the Deputy Chief Scientist to the Space Force. Finally, ION lost Mr. Phil Gibber to COVID-19 in January of 2021. A tribute to him was included in the FY20 Annual Report and I encourage you to read about this amazing individual.

During the year, we welcomed several new personnel to the division. This included Lt Col Melanie Presuto (IO Deputy and EOARD Chief), Maj Grant Thomas (Space Sciences), Mr. Kevin McAllister (RAF Blenheim Crescent Base Ops), and Ms. Angela McLane (Grants Officer) in London; Lt Col Mike Richards (Quantum Science) and Lt Col Garrison Lindholm (Autonomy and Hypersonics) in Tokyo; and Dr. Bradford Barrett (Space Weather and Domain Awareness) in Santiago.

During the next fiscal year, we will continue to pursue the best science relevant to the United States Air Force and United States Space Force. In that pursuit, the International Science Division will look forward to opening a new operating location in São Paulo, Brazil. Our past investments in the region regularly result in high-quality science and we expect our physical presence will further improve connections with this hub of research excellence. We will also finalize planning to open our sixth operating location in Melbourne, Australia.

Thank you for taking the time to read this report. After reviewing these accomplishments, I hope you are as excited as I am about the future of DAF science.

Timothy H Russell

Col Timothy H. Russell, PhD, USAF

Commander, AFRL Det 16 & Director, AFOSR IO

EXECUTIVE SUMMARY AND HISTORY

AFOSR International Basic Science Office

The Air Force Office of Scientific Research (AFOSR), a directorate within the Air Force Research Laboratory (AFRL), is responsible for managing all Air Force basic research investment. The AFOSR mission is to discover, shape, and champion basic science that profoundly impacts the future Air Force and Space Force. As the global R&D community outside the US accounts for approximately 70% of the investment, 80% of the researchers, and over 80% of the technical publications, it is critical to AFOSR's mission to proactively engage the international community. AFOSR's international enterprise consists of four offices: AFOSR/IOE, the European Office of Aerospace Research and Development (EOARD) in London; AFOSR/IOA, the Asian Office of Aerospace Research and Development (AOARD) in Tokyo; AFOSR/IOS, the Southern Office of Aerospace Research and Development (SOARD) in Santiago; and a support division (AFOSR/ION) in Arlington, Virginia, to facilitate integration, communication, and outreach. The call to action in the 2030 United States Air Force Science and Technology Strategy inspired the opening of two additional international offices in Melbourne, Australia and in Sao Paulo, Brazil.

The strategy highlights the urgent need to enact more agile collaboration approaches with both traditional and non-traditional innovators, and these two new offices allows AFRL/AFOSR to do just that. These six international offices constitute a single International Basic Science Office, realizing significant efficiencies in both business operations and technical strategy. The mission is to provide the US Air Force with awareness, engagement, and relationships to international basic research.

In FY2021, AFOSR's International Basic Science Office supported 426 research efforts (primarily grants) performed at foreign universities and institutes from 50 different countries. In addition to funding research projects, we help build relationships between foreign researchers and US scientists and engineers through a variety of programs. This was a challenging year due to COVID-19 restrictions, however, we still supported 8 international conferences & workshops and arranged 14 Windows-on-Science visits of foreign researchers to present their research to AF audiences (12 via virtual meetings). The pursuit of cutting-edge science of AF relevance—both within the US and overseas—remains the singular focus of the AFOSR. The international element of this organization is well poised to shape, leverage, and transition exciting breakthroughs in the years ahead.

www.afosr.af.mil

AOARD/IOA: Asian Office of Aerospace Research & Development

The AOARD office in Tokyo, Japan was established in 1992 and has engaged in basic research outreach in the Asia-Pacific region for the past 30 years. Our role in is to engage, fund and connect scientists and engineers in this region to accomplish basic research in technical areas of interest to the Department of the Air Force. AOARD supports principal investigators by providing funding for research, hosting conferences or funding travel for a researcher to present work at a conference or to scientists at a US Department of Defense Laboratory. AOARD's goal is to promote open basic research, understand the region's scientific expertise and to build long lasting research relationships and collaborations.

Our office also closely coordinates with our sister service basic research offices in the US Army (International Technology Center – Pacific) and US Navy (Office of Naval Research- Global), and the Regional Technology Office in the US Embassy in Tokyo, Japan.

The Asian Pacific region continues to be leaders in worldwide research activity. Nature Index lists 4 of the top 10 countries from the Asia Pacific region (Nature Index Annual, Leading Countries 2020). The following pages will provide highlights of our basic research interaction for the past year.

BIOPHYSICS & MATHEMATICS

The Biophysics and Mathematics portfolio looks for mathematical laws in nature in order to understand, describe, predict, and control the forces that drive biological systems, natural sciences, and social sciences in order to enable new technologies for full mission spectrum operations. Specific areas of research and application include communications, navigation, lethality, power, predictive modeling, and probability and statistics. This portfolio looks to both theoretical and experimental research with a high degree of interest in the modeling of and predictive elements of first principles understanding.

The resources of this portfolio are deployed across a mixture of both large and small projects with both well-established investigators as well as young researchers. In addition, another aspect of this portfolio is the designation of some resources to help investigate problems operational units in the field may be experiencing and attempt to address those problems in a short cycle process. Projects in this portfolio will align with many AFOSR portfolios, AFRL technology directorates, ONRG, JSOC, SOCOM, and other government agencies.

At research institutions across the AOARD region as much of the world, FY21 continued to be a challenging year. Institutions and researchers had to balance laboratory closures, graduate student restrictions, classroom schedules, and government restrictions due to the COVID-19 pandemic. Despite these challenges, some great research was being conducted across the region from cell structure and organization in a zero gravity environment to probabilistic statistics, researchers sponsored by AOARD continued to push the boundaries of science.

IOA Materials, Chemistry, Nanoscience

The design and discovery of new materials is a wide-ranging, interdisciplinary, global endeavor that enables many technological and engineering breakthroughs. Whether experimental or computational, basic research in materials science is often focused on discovering or creating new materials with higher strength-to-weight ratios, improved environmental stability, and/or useful combinations of functional character such as structural, electronic, optical, thermal, catalytic, and self-assembly/healing behaviors.

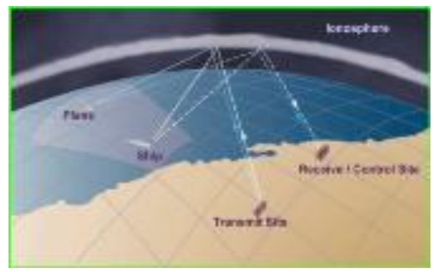
AOARD has long invested in fundamental research into materials science, and this portfolio was newly formed in FY20 to continue this important international venture. The program is broadly concerned with hard and soft materials, organic/polymer chemistry, composites, metallics, and hybrids. Investments target research projects that lead to basic scientific discoveries and advancements in chemical synthesis and characterization, and/or the processing-structure-property-performance paradigm of materials from the molecular- to meso-scales. Approaches may be experimental, computational, or both. Investigations are desired into the design and creation of new molecules and structures, new synthetic pathways and catalysts systems, and/or enhancement of functionalities and capabilities, ultimately resulting in well-understood, controlled synthetic/processing routes. Example interest areas for materials research include multifunctional materials, new materials with exceptional strength-to-weight ratios, 2-D materials and heterostructures, new carbon allotropes and their behaviors, materials with extreme service temperatures, materials demonstrating unique performance in the space environment, hierarchical multiscale materials, stimuli-responsive materials, materials with dynamic functionality, novel bio-inspired materials and structures, breakthroughs in bonding and damage modeling in polymer matrix composites, and on-demand synthesis/processing capabilities.

The portfolio grew from five projects in FY20 to fifteen projects in FY21, with new start projects awarded to PIs in Sri Lanka, India, Thailand, South Korea, Taiwan, and Australia. Investments were made across a range of research topics including hybrid IR-active nanomaterials with controlled core-shell morphologies, chirality transfer in hybrid thin films, tunable organic quantum dot/covalent organic framework nanocomposites, novel low-valent main group chemistry for sustainable catalytic routes, doping strategies for new ceramic functionalities including magnetism, energy transfer phenomena in metal-binding biomacromolecules and organometallics, new redox-active porous organic polymers, novel characterization techniques for 2-D materials, and miniaturization limits of additive friction stir deposition for potential use in space. This project portfolio is strategically collaborative, incorporating technical guidance and co-funding from AFRL/RX, RQ, RY, and RT in order to ensure mission relevance. Program Officer: Dr. Todd Rushing

SENSORS, EM, AND DEVICE PHYSICS

This program explores fundamental concepts and basic research in EO/RF sensors, MEMS, microelectronics, photonics, electro-mechanical, signal processing method, and bio-inspired optical/RF devices to advance current and future Air Force & Space Force capabilities. The basic research areas are: a) Computational electromagnetic (EM) in target, clutter, and background phenomenology modelling, b) Radar (RF) technology in development of algorithm in MIMO, Multi-static, Multi-Spectral, and Distributed coherent radar, data processing/fusion. c) Antenna design such as scalable/programmable phased array antenna, conformal antenna, and new antenna materials for the extreme environment such as the Space. d) C3I, Distributed secured networks, communication, Sensing exploitation, and PNT, e) RF/EO components/devices: Semiconductor, High power solid state amplifier, photodetector, and utilizing quantum computation, and quantum sensing. *Program Officer: Dr. Tony Kim.*

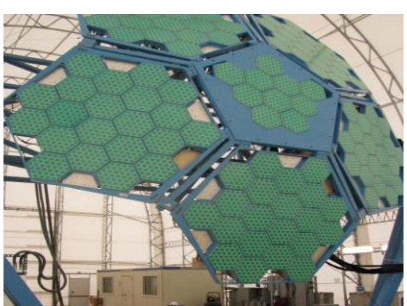
EO Sensing
IR Thermal Imaging



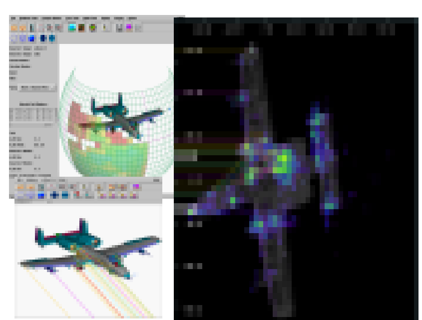
RF Sensing
Next Gen OTH Radar

Sensing Exploitation

Enabling Sensor Devices & components

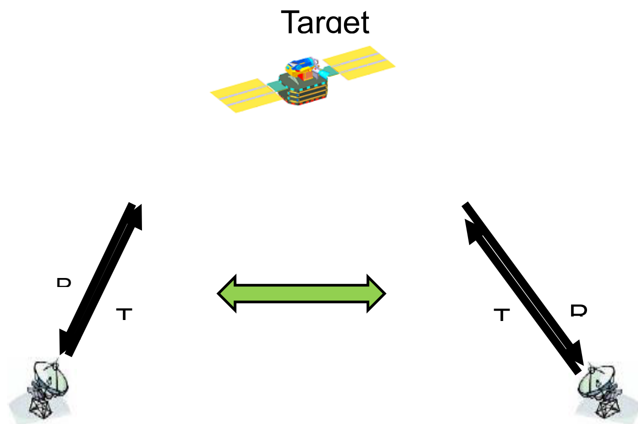


Antenna Design
Geodesic Phase Array Antenna



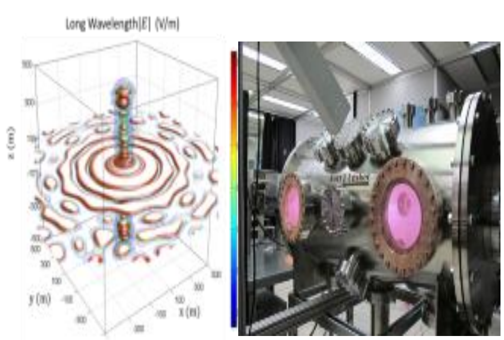
Sensor Signature
& Modeling Validation

Space Situational Awareness (SSA) Sensors. This program seeks revolutionary science on all fundamental research related to EO/RF sensors, Navigation systems, and communication systems for on board Space aircraft and Ground EO/RF sensors looking at either LEO & GEO space. The basic research areas are: a) Processing digital electronics, b) High Power solid-state amplifier, c) Background and clutter modelling & simulation, d), Multi-processing techniques, e) Radar technology in development of algorithm in MIMO, Multi-static, Multi-Spectral, f) Distributed coherent radar, and data processing/fusion. g) Antenna design such as scalable/programmable phased array antenna, conformal antenna, h) new materials research for the extreme environment, dual spectrum material, and limited frequency tx/rx materials. Electromagnetic (EM) scattering, and Irregularity relevant to ionosphere & atmospheric space environment, and experimentally validate theory and simulation models. *Program Officer: Dr. Tony Kim.*

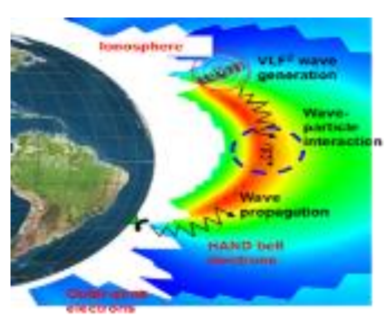


Multistatic/Bistatic Techniques

Hypersonic Sensors. This program seeks revolutionary science on all fundamental research related to EO/RF sensors, Navigation systems and communication systems for on board hypersonic aircraft and weapon system. The basic research areas are: a) conformal AESA for SWAT with RF electronics; b) Processing digital electronics; c), High Temp Material for the Radom, IR window, and Frequency selective materials (programmable materials for multispectral); d), Gimbal technology to compensate for platform velocity/shock/vibration; e), Multi-processing techniques; f) Plasma turbulence, EM scattering, and Irregularity relevant to ionospheric/atmospheric space environment. Empirically observe and characterize important nonlinear plasma phenomenology, and experimentally validate theory and simulation models. *Program Officer: Dr. Tony Kim.*



Plasma Sim/Testing



Ionosphere Phenomenology

A few of the success stories:

- Potential Technology transition to the ARL.

  The project "Exploring Deep Learning-based" is co-funded with ITC IPAC, DEVCOM/ARL, AFOSR, & AOARD and when the project completed, concept will be transfer to the ARL for further test & evaluation.

- Some publications, papers, patent during 2021 even though limited travel and meetings.
  - Published on "Light-Fuelled Climbing of Monolithic Torsional Soft Robots via Molecular Engineering" in Advanced Intelligent System.
  - Published on the "Magnetically programmable soft material" in ACS-Nano
  - Published "Effect of Co-Solvent Percentages on the Exfoliation Rate of NiTe2 Thin Film for Transparent Electrodes" in Material Matter.
  - Patent on "Anode-free rechargeable lithium metal battery comprising an ion conductive layer and transition metal dichalcogenide layer and manufacturing method thereof" (KR1020210096212)

AEROSPACE SCIENCES

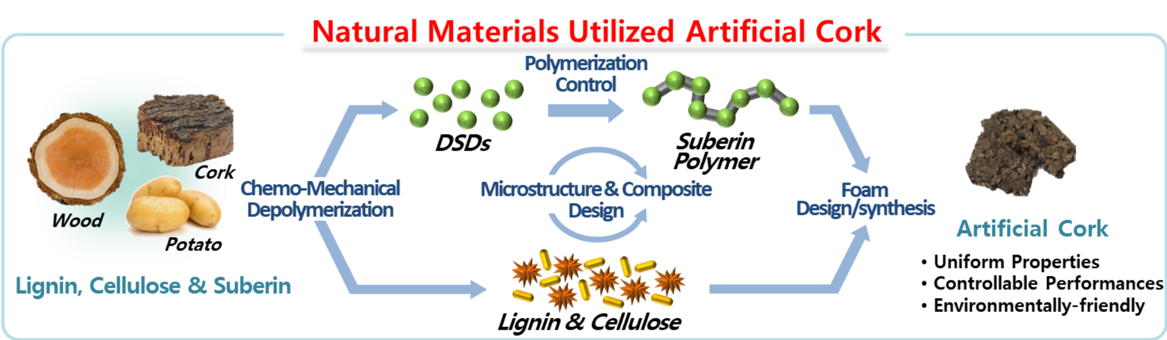
The AOARD Aerospace Sciences portfolio primarily studies challenging problems in aerodynamics characterized as high-speed, unsteady, or non-equilibrium flows. High speed flows include supersonic and hypersonic boundary layer transition, shockwave boundary layer interactions, heated walls, and ablation. Unsteady flow topics include turbulence, novel control actuators, surface interactions, and flow characterization and modelling. Features of non-equilibrium flows include combustion, propulsion, and non-equilibrium thermodynamics. Cross-cutting technologies promising improvements in aerial flight are also of interest, including: multi-physics vehicle design and optimization, bio-inspired flight, innovative data exploitation for predictive models, and novel techniques for flight testing. Successful projects in this portfolio will align with U.S. based AFOSR portfolios, and link to other AFRL technology directorates.

New start grants in FY21 were awarded in Australia, India, Japan, Malaysia, Taiwan, and Thailand. The majority of these grants were awarded to new professors, in their first year or two of research after completing a PhD or post-doc. This was a deliberate strategy to recruit new talent who can work with AFOSR for years to come. Looking forward into FY22, topics for potential grants include quantum algorithms for computational fluid dynamics, machine learning applied to non-equilibrium/rarefied flow calculations, and increased push for advanced propulsion concepts such as rotating detonation engines.

MATERIALS DISCOVERY AND MANUFACTURING SCIENCE

This program broadly covers the exploration of new material systems and the use of autonomous experimentation for materials discovery and manufacturing optimization. New materials systems of interest include nature-inspired materials, high-entropy alloys, magnetic materials, programmable materials, flexible electronics, materials for extreme environments, multifunctional materials, and nanoscale materials and structures. In addition, the program seeks to be responsive to new DoD priorities in microelectronics and Space. In particular, 2D materials such as transition metal dichalcogenides (TMDs) have potential to support major advancements in microelectronics such as smaller transistors as well as high radiation environment functionality and edge computing for Space. In addition, natural materials systems such as specialized wood and cork are also being explored for Space applications. Single photon source materials for quantum applications, material systems for additive manufacturing, 3D and 4D printing. The country initiatives with Taiwan and Korea on nanotechnology are aligned with this program. The program seeks new partners in the Association of Southeast Asian Nations (ASEAN). Close interaction with AFRL Technical Directorates (RX, RQ, RV, and RH) guides the focus and ensures the relevance of this program to the Air Force. Lastly, this program aligns with and supports domestic AFOSR programs such as Condensed Matter Physics, Multiscale Structural Mechanics and Prognosis, GHz-THz Electronics and Materials, and Low Density Materials. *Program Officer: Dr. Jeremy Knopp.*

Project 18IOA035 at Sungkyunkwan University with Prof. Jonghwan Suhr was completed this year. Cork is a natural and renewable material that exhibits intriguing material properties. However, due to its non-uniform material properties caused by its chemical composition, cork has limited applications despite outstanding damping and insulating properties. Currently, research is supporting artificial cork synthesis such that the properties can be designed and once designed, can be 3D printing. In other words, cork that wasn't designed by nature is being 3D printed. The intrinsic material properties of include: light-weight (0.12~0.2 g/cm^3), near-zero Poisson coefficient, elastic and highly deformable under compression without fracture, high damping, low electrical (2.9 x 10^{-14} S/m) and thermal (0.04 W/mK) conductivity. The result of this work is a material that is can be used as a sandwich panel core material that has tunable damping capability which can be used in aircraft, UAVs, and electric vehicles. The material is also recyclable. In this course of this project it was learned that one of the PhD students is a US citizen and interested in doing a Post-doc in AFRL/RX. Given that wood is being consider by Japan for a satellite material, it is envisioned that cork (yes, the wine bottle type of cork) may one day be in Space.



Project 20IOA060: Various news stories have shown the desire for cooperation with South Korea on COVID-19 testing, and that South Korea has received requests from 121 countries for help with coronavirus testing:

https://www.reuters.com/article/us-health-coronavirus-southkorea-testing/over-100-countries-ask-south-korea-for-coronavirus-testing-help-official-idUSKBN21J51C

The phase 3 extension of AOARD's US-Korea Nano Bio Info Technology (NBIT) program that ended in 2017 included revolutionary research on building pieces of a lab on a chip that could facilitate mass testing for biomarkers which is now pertinent to COVID-19 rapid response efforts. Prof. Luke Lee who was at University of California - Berkeley at that time and now at Harvard Medical Center teamed up with Prof. Taewook Kang at Sogang University in South Korea. This project was granted a rare extension for a 4th year, and provided the foundation for development of a “Speedy Accurate Nanophotonic Diagnostics System” in order to create an ultrafast and ultrasensitive photonic PCR-based COVID-19 diagnostic system.

This team will study the fundamental science of (1) quantum biological electron transfer to understand the mechanism of ultrafast quantum plasmonic PCR, and (2) quantum plasmon resonance electron transfer (QPRET)-based PCR for rRT-PCR and immuno-PCR on a chip. These studies will generate broad ranging impact and innovative future applications in molecular diagnostics for COVID-19 and the precise identification of any other viruses or pathogens. With intimate collaboration between Prof. Luke Lee’s group at Harvard Medical School, USA, and Prof. Taewook Kang’s group at Sogang University, Korea, this team will focus on the elucidation of a quantum biological heat engine, quantum biological tunneling in enzyme reactions, quantum effects in DNA and enzyme reactions during replication, and the investigation of a resonant electromagnetic wave to enhance enzyme activity.

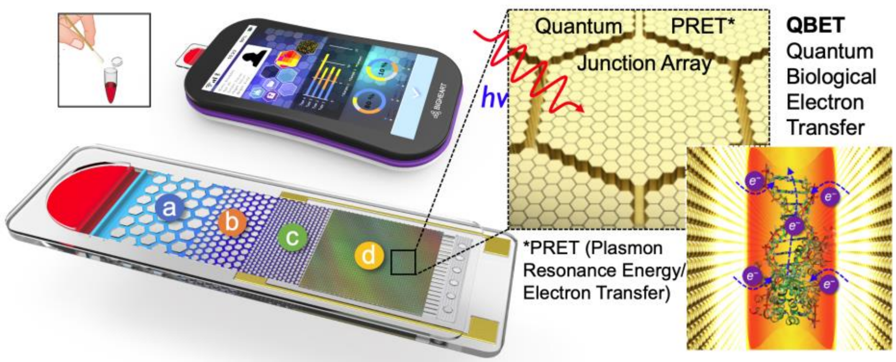


Figure: Fundamental research leading to a precision PCR chip for the home diagnostics of infectious disease.

Work continues on project titled "GaN Modeling and CAD" with Macquarie University in Sydney, Australia. This program, now in its third year, is managed and executed by RX (Bryan Sanbongi), RY (Tony Quach) and AOARD (Jeremy Knopp). During the review, the modeling methodology for MQFET (Macquarie Field Effect Transistor) was transferred to AFRL. Macquarie University’s GaN modeling approach, first supported by the AOARD grant, has gained significant credibility with US Industry and Australian stakeholders to the point where the original research grant of $300K over 3 years has been leveraged with $6M in additional external funds (20x the original investment) provided by Analog Devices (USA), MicroSemi (USA), and DST (Australia). This program review was held in conjunction with MU’s first annual MQFET model user group workshop. AFRL’s sponsorship of this program will enable first pass design success and faster delivery of next generation radar systems for US DoD warfighters. The decision was made to provide additional funding to the current program to make use of new characterization methods for higher fidelity models.

Figure: Dr. Jeremy Knopp mesmerized by results presented by Mr. Bryan Sanbongi (RX) and Dr. Tony Quach (RY)

QUANTUM ENGINEERING

This portfolio encompasses those research efforts that seek to elucidate or exploit the unique phenomena associated with quantum physics in areas such as: quantum sensing, quantum communications, and quantum enabled calculations. The domain of quantum sensing includes superconducting, Bose-Einstein condensate, and atomic interferometric method to sense motion and electromagnetic fields. The field of quantum communication enables guaranteed eavesdrop-free communication channels built by using entangled states. Quantum calculations include both quantum simulations and new algorithms and hardware needed to acquire solutions not easily accessible with classical computers.

Beyond the core efforts within this portfolio, in FY21 the Innovare Advancement Center, in conjunction with the AFRL Information Directorate, AFOSR, and the Office of Naval Research awarded six grants to researchers within AOARD's area of responsibility through the Million Dollar International Quantum U Tech Accelerator program.

This portfolio interacts closely with AFRL Technical Directorates (RI – Information Directorate, RV – Space Vehicles Directorate, RX – Materials Directorate, RY – Sensors Directorate, RD – Directed Energy Directorate) to guide the focus and ensure relevance back to the mission of the Air Force. In addition, there is also great interest, collaboration, and funding with DoD partners from the Office of Naval Research Global (ONRG) and Army. Program Officer: Lt Col Mike Richards

The project focusses on digital strategies for aircraft structures in robotics. The objective of the program is to develop fundamental knowledge and understanding of computational design related to aircraft structures and robotics. The development of aircraft (including spacecraft) needs the creation of revolutionary products or production methods that have never previously existed. Additional consideration is directed to innovative robotics on the next generation of cyber-physical system. Critical issues on the topic include what we need for the new system philosophy on aircraft structures and robotics. Projects should address one or more of the following : [1] to establish innovative process control strategy for newly developed materials used in aircrafts and robots, [2] to develop aerial robots by analyzing flapping wave aerodynamics both from theoretically and experimental point of views, [3] how to design the complex network system using newly developed sensors and multi-objective robots in the coming cyber world, [4] to develop the innovative navigation methods using artificial intelligent techniques in order to develop newly aerial robots.

AusOARD/IOAM: Australia Laboratory Liaison

AusOARD – IO’s newest office coming in 2022!
AFOSR will be opening an office in Melbourne, Australia in late 2022, recognizing Australia as a key FVEYs partner and world leader in STEM. We currently have 56 active grants worth over $12 million, with research at 17 different institutions. The majority of these grants will continue to be managed from our Asian Office of Aerospace Research and Development (AOARD) in Tokyo, but a local presence is seen as essential in providing more direct and responsive engagement. Indeed, the plan for the future is to enhance our interaction with Australian researchers and to pursue a greater number of collaborative efforts, directly with AFRL. Areas of particular interest will be space, quantum and optical physics, aeronautics (hypersonics) and information technology.

AFOSR will staff a satellite office in Melbourne, Australia with two Laboratory Liaison Program Officers in late 2022 or 2023. The new satellite location will be co-located with our scientific counterparts in Australia’s Defence Science and Technology in Group in Fisherman’s Bend. The Australian satellite office will report to and coordinate actions with the AOARD office in Tokyo, Japan. The founding and opening of the Australian office signifies the strength of Australia’s research capability and provides another link in the bilateral US-Australia defense partnership.

There will be two roles for the Laboratory Liaison Program officer: 1) they will continue to engage and fund basic research of interest to the Department of the Air Force and 2) they will be a liaison officer to assist in the managing of the applied research collaborations between Defence Science Technology Group researchers –Air Force Research Laboratory researchers.

AFOSR - Australia Office will be located at the Fishermans Bend in Melbourne, Australia

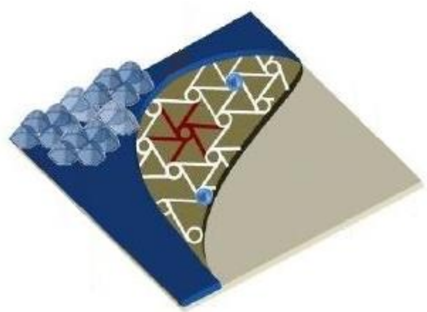
EOARD/IOE: European Office of Aerospace Research & Development

The oldest of AFRL's overseas offices, the European Office of Aerospace Research and Development, or AFOSR/IOE (EOARD), was originally established in Brussels in 1952. Under the now defunct Air Research and Development Command, EOARD moved to London in 1970, and then realigned under AFOSR in 1974. Throughout its 70-year history, the office has maintained the primary mission of engaging the European scientific community to support and leverage emerging basic research of interest to the U.S. Air Force; now adding support to the U.S. Space Force, we focus on interests for the ***Department of the Air Force*****.** The EOARD geographic area of responsibility includes Europe, the Middle East, former Soviet states, and Africa. The EOARD is a partner organization to the International Science and Technology Center (ISTC), and the Science and Technology Center in Ukraine (STCU) to facilitate projects in former Soviet states. Based in Greater London, EOARD is co-located with other scientific outreach and support offices, including those of the Office of Naval Research Global, U.S. Army International Technology Center-Atlantic, and the Canadian Forces Support Unit Detachment London.

Chief: Lt Col Melanie M. Presuto | Contact: DSN (314) 235-6011, eoard.orgbox@us.af.mil

Advanced Aerospace Materials and Structures

The Advanced Aerospace Materials and Structures portfolio seeks revolutionary basic science in the disciplines of physics, mathematics, materials science, structural mechanics and aeronautical sciences to enable new technologies for aerospace structures with United States Air Force and United States Space Force relevance. This portfolio has two central pillars: energy efficient structures and structures for extreme environments. Energy efficient structures are those which reduce operational costs or enable increased speed, range, or payload through innovative means such as reconfigurable and novel flight structures. Fundamental research in this area is supported by many disciplines including structural mechanics, aeroelasticity and materials science. Structures for extreme environments are those subjected to loads from high temperature, high frequency, or high strain rates with special emphases on coupled multi-physics phenomena and combined loadings. This portfolio, therefore, supports research toward material characterization under high strain rate loading and hypersonic-enabling science. Supporting these two pillars are two foundational areas of study:



Multistable composite with tunable global and local morphing capability inspired by the muscular-skeletal structure of a bat's wing.

computational modeling and materials development. Computational modeling includes focuses on multi-scale and multi-physics simulations as well as optimization techniques, all of which will enable efficient and extreme environment structures. For materials development, the focus is on next generation composites, smart materials, and adaptive and multifunctional structural materials. More information about the goals, objectives, and activities of the Advance Aerospace Materials and Structures portfolio can be found at https://community.apan.org/wg/afosr/w/researchareas/11157.advanced-aerospace-structures/ Program Officer: Maj David Swanson

SPEED AND REACH OF DISRUPTION AND LETHALITY HYPERSONIC FLIGHT

FY21 Research Highlights

As an enabling technology for the AF 2030 S&T Strategy, hypersonic flight research has a strong presence in the AFOSR International Office. Collaborations are taking place between multiple AFRL Technical Directorates (RQ, RX, RW, and RV) and various international research organizations, including the UK's Dstl, Australia's DST-G, the NATO-supported von Karman Institute, and Germany's DLR. Research activities funded by IO also strongly support the goals of the High Speed Aerodynamics program at AFOSR, with projects underway in shock/shock and shock/boundary layer interactions, ablation, high temperature effects, boundary layer transition, high temperature materials development, and fluid-structure interactions. Other AFOSR programs are also supported, including the Energy, Combustion and Non-Equilibrium Thermodynamics program and the Aerospace Materials for Extreme Environments program. A sampling of research projects that are in direct support of AF 2030 S&T Strategy and AFRL hypersonic goals are described below. This year these samples summarize two recently-concluded efforts focusing on the gas thermo-chemistry of high-speed flight, and gas-surface interactions arising from thermal protection systems.

SMALL-MOLECULE REACTIONS RELEVANT TO THE HYPERSONIC FLIGHT REGIME

Project 1: Dr. Markus Meuwly, University of Basel, Switzerland

Aircraft traveling through the atmosphere at hypersonic Mach numbers dissipate large amounts of energy in to the surrounding gas and generate highly non-equilibrium conditions in the surrounding molecules. Typically, the energies (and hence temperatures) are sufficiently high to dissociate small molecules such as N_2 and O_2. Under such extreme flow conditions, local heating, surface ablation, control surface authority and plasma formation are directly sensitive to the energy distribution in molecules and atoms. Yet, the gas-gas and gas-surface reactions and energy transfer at these temperatures are essentially uncharacterized and the experimental methodologies capable of probing them are not well established. Under such circumstances, validated computational chemistry investigations become a valuable tool. The overall goal of this research was to apply computational chemistry methods to the reaction dynamics involving C-, O-, and N-atom-containing species under hypersonic flight conditions. Of particular interest was the computation of temperature-dependent reaction rate coefficients, branching ratios, and cross sections that serve as the primary input for more coarse-grained simulations. This research involved multiple steps including electronic structure calculations, efficient representations of potential energy surfaces (PES), and state-to-state cross-section modeling. The initial work involved calculations of electronic structure and determining PES reference data. The *ab initio* PES data was then represented using a reproducing kernel Hilbert space approach. For reaction simulations, the nuclear dynamics of a particular reaction can typically be examined using a quasi-classical trajectory approach, but as the scale of simulations increases, this approach becomes numerically impractical. To overcome this limitation, the team explored how a machine learning model based on neural networks from explicit QCT data for state-to-state cross sections can be applied to reactive and non-reactive state-to-state cross sections. These ingredients then enable more coarse-grained simulations of the state distribution of the species required to characterize the nonequilibrium chemistry around hypersonic vehicles. Moreover, the work demonstrated that atomistic simulations provide the necessary quantitative insight into nonequilibrium distributions for the different degrees of freedom that are required for rarefied flow and flow on small length scales relevant in hypersonics. This project was co-funded with AFRL's Space Vehicles DIrectorate (AFRL/RV), with results being applied to AFOSR-funded numerical codes being developed at The University of Minnesota.

Project 2: Dr. Thierry Magin, Von Karman Institute (VKI), Belgium

An aircraft traveling at hypersonic Mach numbers through the atmosphere is enveloped by a strong shock wave and a boundary layer of high enthalpy gas. The resulting chemically-active boundary layer reacts with the vehicle thermal protection system (TPS) leading to gas-surface interaction (GSI) phenomena. Recently concluded work at VKI examined physico-chemical modeling of reaction behaviors for gas surface interactions of different thermal protection materials. The work was focused in three areas: (1) a VKI experimental campaign examining ablation phenomena of graphite in nitrogen plasmas, the nitrogen ablation tests provide experimental data for the further development of phenomenological models of the surface nitridation process and the surface reactivity to nitrogen recombination; (2) modeling of complex GSI phenomena including finite-rate chemistry and thermal non-equilibrium, and within this framework, equations describing thermal non-equilibrium at the surface were derived and included in the Mutation++ library; and (3) including and validating the finite rate chemistry model derived by Prof. Schwartzentruber (University of Minnesota) in the Mutation++ library. The VKI team also provided help to the Minnesota team for the coupling of the Mutation++ library with their US3D solver, making available both the gas surface interaction model and gas phase state-of-the-art modeling.

Mathematics and Operations Research

This research portfolio supports basic science through innovative mathematics and machine learning theory and algorithm research of relevance to the United States Air Force. The quantity and complexity of data collected in support of U.S. military and government operations and the requirement for increasingly faster decisions makes it imperative to leverage operations research and machine learning methods to analyze and extract meaningful information from the data. The explosive growth in machine learning capabilities, initially fueled by computer hardware improvements and then sustained by continuous algorithm development, has been central to meeting this requirement and an accelerant for almost all other research areas funded by the Air Force.

Another challenge this portfolio seeks to address is that of communication and network bandwidths being unable to meet the demands of transmitting and processing the unprecedented amounts of data collected by sensors. This disparity necessitates innovative research in information theory and data fusion to reduce bandwidth needs and algorithm research for small, lightweight, low power machine learning computing capabilities deployable in an embedded computing environment such as those provided by neuromorphic computing. This portfolio supports research to meet these requirements and the ever present need for efficient logistical operations through advances in stochastic modeling, multivariate analysis, optimization, information theory, and machine learning algorithms. For further information about the goals, aims, and activities of this portfolio, please contact the EOARD Mathematics and Operations Research Program Officer, Lt Col Mark Friend.

Physics & Space Sciences

The physics portion of this portfolio has a special focus on quantum information and quantum sensing, solid-state physics, photonics, atomic and molecular physics, and electromagnetics with most projects looking toward enabling quantum enhanced systems that exploit entanglement. In space science the aim is to advance the understanding of the space environment to improve space situational awareness (SSA) to protecting orbiting assets, and understand its impact on communication, navigation, and other programs of relevance to the Air Force. Focus areas for this program include solar storm prediction and transport through the inner heliosphere; radiation and energetic particle distributions occurring in quiet conditions or from storm events; bottom-side structure of the ionosphere and its impact on radar propagation; prediction and trigger mechanisms of ionospheric scintillation and associated plasma instabilities; thermospheric dynamics (energy deposition, neutral winds, etc.) and its effects on atmospheric drag on satellites; and the atmospheric physics which impact satellite communications at various frequencies. Current instruments and models have advanced the state of the art over the past decade, but more accurate predictive modelling and simulation is needed. New instruments and models, particularly coupled models, are needed to understand and forecast significant space weather events. Research institutions in Africa provide an opportunity to explore atmospheric physics in a unique region. Because of the potential global implications, interest in space science research is growing worldwide, providing an excellent opportunity to leverage the research investment across the community. Where possible the funded science and research groups communicate with Air Force researchers to be aware of and look toward future Air Force applications. Further information about the goals, aims, and activities can be found at Physics and Space Sciences - Research Areas - AFOSR - APAN Community or by contacting the EOARD Program Officer, Dr. Scott Dudley

AERONAUTICAL SCIENCES

This portfolio covers a wide range of fundamental science problems under the heading of Aeronautical Sciences. Aeronautical Sciences includes science and technology associated with enabling flight in air across all flight regimes. There are two research focus areas within this program: 1) Aerodynamics, covering fundamental science associated with the motion of air (or other fluids), particularly when interacting with a body—the relevant challenges in this area include hypersonic flight, flow physics for aerodynamic control, unsteady aerodynamics, boundary layer physics (esp. transition, turbulence, and shock-wave interactions), and fluid-structure interactions; and 2) Air Breathing Propulsion, covering fundamental research associated with all aspects of air-breathing and access-to-space propulsion including improved performance of conventional engines, enabling capabilities for supersonic combustion engines, turbulent combustion, and novel engine concepts. Further information about the goals, aims, and activities for this portfolio can be obtained by contacting Program Officer*, Dr. Douglas Smith*, at eoard.aer@us.af.mil.

LIFE SCIENCES AND HUMAN PERFORMANCE

Life Sciences and Human Performance: This portfolio aims to gain a mechanistic understanding of biophysical, biochemical, and bio-engineered principles useful in enabling, enhancing and sustaining human performance. As such, the covers a broad range of human performance knowledge areas such as neuroscience, novel sensors, systems biology, human-machine teaming, bio-resilience, computational and cognitive models, language technologies and bio-signatures. Of particular interest in this portfolio is synthetic biology to enhance human performance, novel models and techniques for bio-sensing, bio-resilience and protection and the science of understanding the symbiotic partnership of humans and machines that operate in agile and flexible ways. For additional information about the goals, aims and activities for this portfolio, please contact the International Office Europe (IOE) Life Science and Human Performance International Program Officer, Dr. Nandini Iyer

SENSORS AND MICROELECTRONICS

The Sensors and Microelectronics portfolio aims to advance science for the utilization of the electromagnetic spectrum (EM) with United States Air Force and United States Space Force relevance. The portfolio focuses on basic, exploratory and developmental research on RF and EO/IR sensor systems, precision navigation and timing (PNT), signal and image analysis and target recognition methods, and their enabling technologies utilizing material science, microelectronics, photonics, and heterogeneous integration of materials, components and circuits. The incredibly wide range of the research portfolio covers any aspects of these electromagnetic spectrum sensor relevant technologies at any vertical level from materials to systems.

Current projects in material science for EM sensor technologies include exploring beta gallium oxide for high power RF transistors and switches, gallium oxide for nonlinear optical materials, highly tunable 2D metasurfaces, growth processes of InAs for EO/IR sources and detectors, multiple metamaterial related projects, additive manufacturing with sol gels, materials for extreme environments of IR radiations, and chemically engineered chromophore based nonlinear optical materials.

Examples of component and circuit exploration projects include non-foster materials for negative impedances for broadly tunable RF components, non-reciprocity in optical and microwave systems, waveguide based cavity for high power IR lasers, chaotic waveform modulated LIDAR based on optical combs, high temperature quantum cascade EO/IR detectors, photonic FPGAs for broadband tunable RF filters, and low phase noise, highly tunable compact microwave oscillators based on photonics.

Among methods and concept of operations for exploiting the electromagnetic spectrum are projects that investigate techniques for cognitive RADAR, coherent multichannel RF signal fusion and processing, coherent RF signal distribution to MIMO RADAR through photonics, and propagation characteristics of V and W band satellite communication channels through the atmosphere.

More information about the goals, objectives, and activities of the Sensors and Microelectronics portfolio can be discussed by emailing to the International Program Officer: Dr. Attila Szep

SPACE SCIENCE

The space science portfolio seeks to find and fund transformational international research and paradigm- shifting ideas in Space for future Air and Space Forces. International interest and investment in space related research continues to grow. To meet that demand and facilitate cross-discipline investment in space research, the European space portfolio is now aggregated under consolidated leadership. This renewed space focus acknowledges that to gain and maintain space superiority of the future, critical scientific investments are needed today. Future space operations demand an increasingly sophisticated domain awareness both in terms of quality and quantity. Constellation sizes are growing while detectable satellite signatures decrease with proliferation further away from Earth. To thrive in the increasingly competitive and contested domain, satellites need to be more autonomous, resilient, interoperable, flexible, and responsibly operated within the domain. This portfolio has three central pillars to address the capability gap and develop the science necessary for future exploitation: space domain awareness, astrodynamics, and next generation satellite enablers. Space domain awareness includes research into novel satellite detection and characterization methods, advanced sensors and sensing techniques, daytime exploitation, automated decision making, and environmental monitoring. The Astrodynamics pillar focuses on developing the fundamental science to successfully operate and maintain awareness in cis-lunar and orbits beyond GEO. In this regime, third-body perturbational effects are increasingly significant and efficient maneuvers make orbital propagation challenging. Orbital debris management is also critical to preserve the environment for future operations as the number of maneuverable and passive space objects continues to rise. The next generation satellite pillar includes a curated investment in the pervasive space technological advancements required for increased on-orbit resiliency and survivability, advanced communication, power, and thermal management for the spacecraft. More information about the goals, objectives, and activities of the Space Science portfolio can be found at HYPERLINK or by emailing the Program Officer, Maj Grant Thomas

SOARD/IOS: Southern Office of Aerospace Research & Development

Main Office – Santiago, CHILE

Second Office – São Paulo, BRAZIL

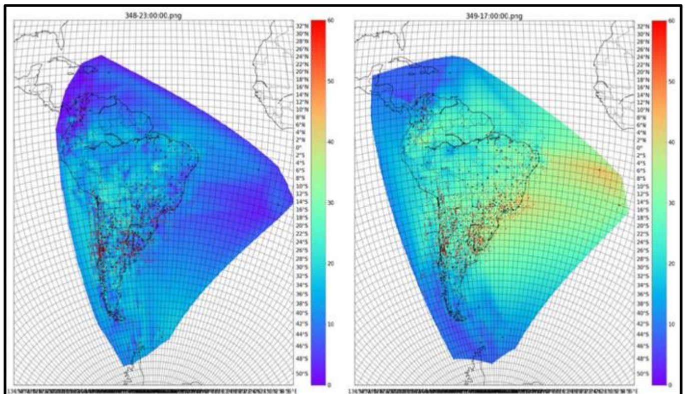
SOARD was established in Santiago, Chile in 2009 to engage the rapidly emerging Latin American scientific community. Similar to its sister offices of AOARD and EOARD, SOARD is co-located with the Army's Combat Capabilities Development Command - International (DEVCOM-ITC) and the Office of Naval Research - Global (ONRG). Headquartered in the U.S. Embassy in Chile, SOARD promotes scientific advancements of interest to the U.S. Department of the Air Force by coordinating research with the leading scientists of Mexico, the Caribbean, Central, and South America in partnership with AFRL investigators. In 2022, the AFOSR International Division will proudly open an additional SOARD location in the U.S. Consulate in São Paulo, Brazil.

In 2021, SOARD managed 58 scientific projects in 10 countries, supporting 150 researchers, resulting in over 80 journal publications, 170 conference presentations, and over 70 new collaborations. SOARD members also play a unique role as science attachés to the U.S. State Department where, together with the U.S. Department of Defense and U.S. Southern Command, they promote science and technology cooperation with multinational government agencies and support research and development efforts with partner nations. Each Program Officer at SOARD covers a wide range of scientific disciplines. This broad approach, expanded by its newest two-office structure, helps SOARD develop unique and multidisciplinary research collaborations and leverage the unique capabilities of scientists throughout Latin America.

Chief: Lt Col (Dr.) Dan Montes | Contact: LatinAmericaScience@state.gov

LATIN AMERICA – SPACE AND SENSING

The space and sensing portfolio connects with a key area of substantial expertise in the Latin American research community. For example, with Chile being the host to over 70% of the world's major astronomical facilities, with significant multinational research investment, many of our research grants have concentrated on space domain awareness and space weather. Our scientists study important physical features, including the magnetic equator that passes through the heart of South America and is monitored by a network of scintillation stations located throughout the region. SOARD also finances important research into understanding the ionosphere perturbations that affect GPS and communications. This work is necessary for predicting satellite drag and radiation belt perturbations, and it is useful in maintaining space situational awareness and for protecting AF and SF communication, navigation, and surveillance assets in space. Beyond the ionosphere and thermosphere, we are also interested in nanosatellites, and we are funding the launch efforts for the Satellite of the University of Chile for Aerospace Investigation (SUCHAI) II and III satellites. As part of this portfolio, SOARD is invested in the physics of sensing, with optical and quantum physics being at the forefront of the projects we fund. We have a number of grants supporting research into the Classical-Quantum divide, while others are looking at producing quantum states for communications and computing. Meanwhile, the optical physics areas of interest are aimed at imaging concepts such as remote sensing and resolution enhancement techniques. Program Officer: Dr. Bradford Barrett, LatinAmericaScience@state.gov.



TEC over Chile and South America on a) December 13 (day before the Eclipse) and b) 14 of 2020 (time of the total eclipse in Chile) using GPS satellite network. (Courtesy of J. Valdivia)

LATIN AMERICA – CHEMISTRY, MATERIALS, AND BIOLOGICAL SCIENCES

The Chemistry, Materials and Biological Sciences program range is as diverse as the geographical area covered, with research focus areas best captured in AFOSR's current BAA. However, there is special emphasis placed on the unique investigations primarily found in Mexico, South and Central America - due either to their wealth of expertise (materials research) or in the rare geographical phenomena found within (Antarctic extremophiles, high altitude research, etc.). Research areas are strongly tied to those of interest to the AFRL technical directorates, particularly the 711th Human Performance Wing (711 HPW), Materials and Manufacturing Directorate (RX), Munitions Directorate (RW), and Aerospace Systems Directorate (RQ, Edwards).

Current areas of funding (research interest is not limited to these fields):

- Chemistry: Research of supramolecular architects, non-destructive surface characterization techniques, chloride-doped temperature-dependent crystal structures, and biochemical mitochondrial transfer mechanisms

- Biology: Inquiry into extremophile enzymes and mechanisms of survival evolution, virus specific promotor sequences for detection, and retinal sensor mechanisms
- Materials: Efforts into novel materials and computational modeling efforts for damage evolution/prediction, energy harvesting, interface/interphase frameworks, and micro/macroscale linkages

Program Officer: Dr. Stacy Manni, LatinAmericaScience@state.gov.

LATIN AMERICA – INFORMATION SCIENCES, HUMAN SYSTEMS INTERACTION, MATH, AND AERONAUTICS

SOARD seeks cutting-edge research within the information sciences, math, optimization, and advanced computing. Areas of interest include big data fusion and analytics, improved algorithms and novel modeling techniques, uncertainty quantification, resource allocation, planning, logistics, engineering design and scheduling, machine learning, and cognition and reasoning. The eventual application of these topics can inform complex networks, robust decision making, performance, operational efficiency, and optimal control of dynamical systems, and autonomy and information technology. Recent efforts have explored topics like population behavior during the COVID pandemic, human trust of automated partners, and the ability for robotic vehicles to establish adhoc communications networks. Within the aeronautics discipline, grants typically investigate unsteady aerodynamics, turbulence, and thermal issues, particularly as applied to hypersonic aircraft. Recent projects include stability studies, computational fluid dynamics (CFD), and surface flow over wings. Program Officers: Dr. Dan Montes and Dr. Chris Carson, LatinAmericaScience@state.gov.

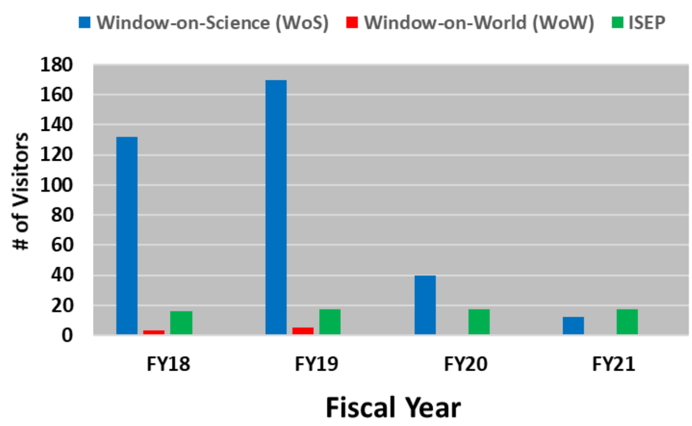
ION - International Office - North

AFOSR's International Division in Arlington, Virginia, (AFOSR/ION) provides critical links between the overseas offices and customers and colleagues based stateside. It is responsible for a range of activities and programs that either must be run or are most efficiently run from AFOSR's headquarters. Responsibilities include technical data analytics; personnel exchanges to and from AFRL and affiliated sites; liaison with other DoD federal agencies; assistance in developing collaborative international programs; and representing the international community in drafting of AF and DoD plans and strategies. ION's work is a mixture of specific programs and the development of new activities.

Chief: Dr. Thomas Kim

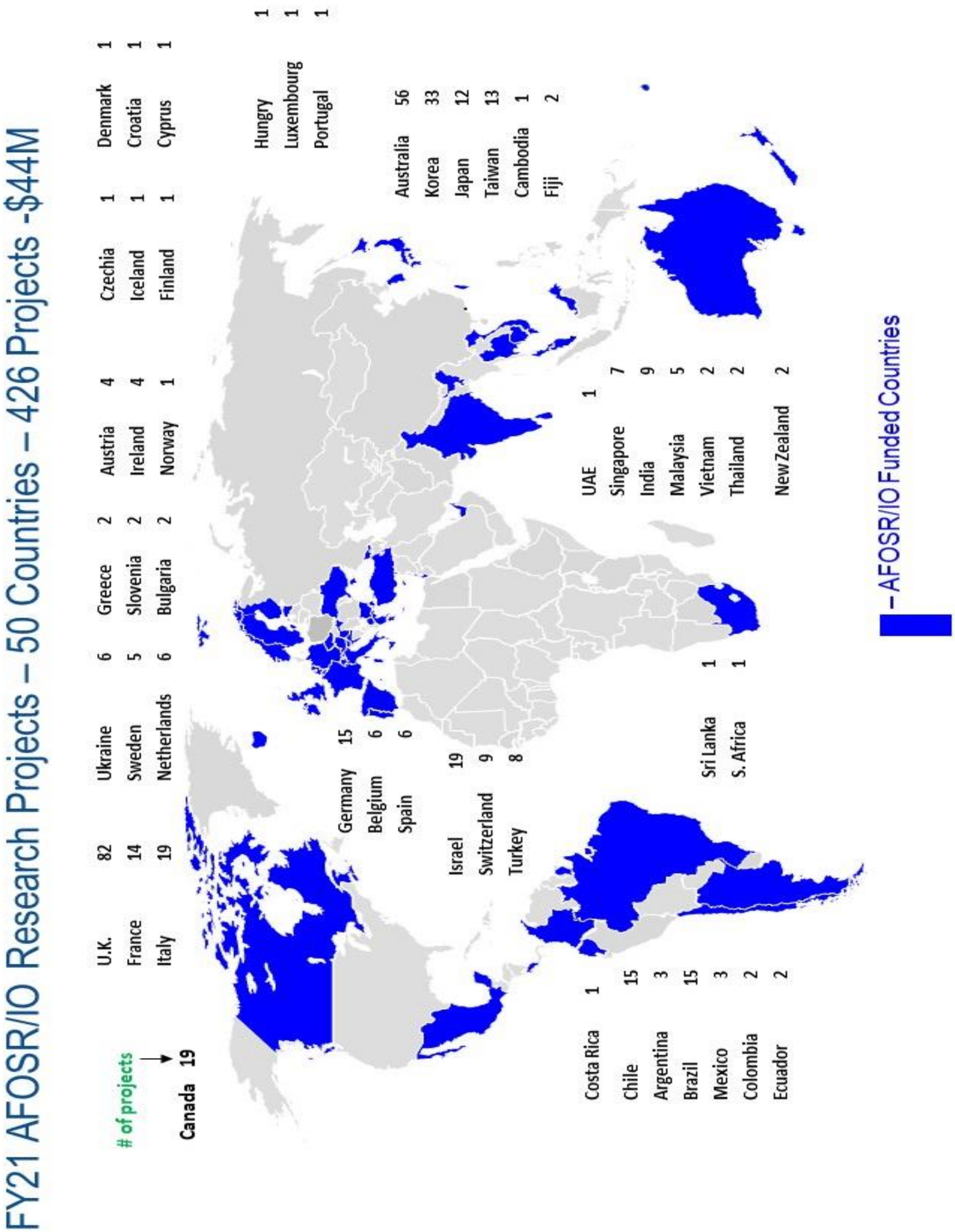
The following ION programs are means to accomplish the IO mission and strategy. The IPOs augment these programs with IO's three strategic pillars – awareness, engagement, and relationships to maximize return on the international investments.

- The Window-on-Science (WOS) program is an invitational program for prominent international scientists and engineers to visit and forge lasting collaboration with AF researchers. Visitors provide a seminar on their research activity and have the opportunity to engage in technical discussions with their AF counterparts.

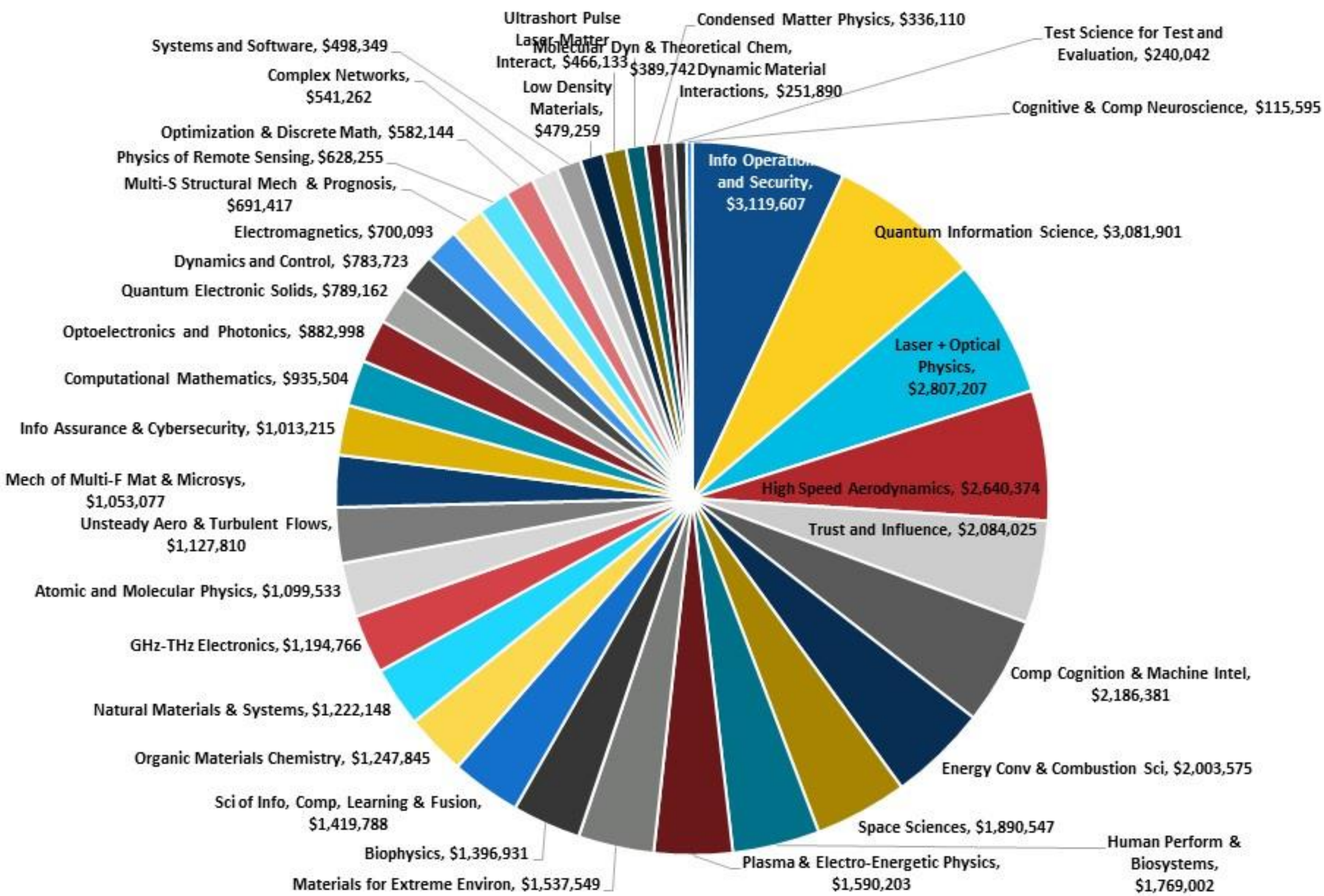


- Windows on the World (WOW) – This program provides funding support for AF scientists and engineers to perform invited short-term research (2 weeks to 6 months) in a foreign laboratory, collaborating side-by-side with international S&T leaders.
- International Student Exchange Program (ISEP) – This program provide funding to one of current AFOSR PI's graduate students to work with an overseas collaborator, or the opportunity for an overseas collaborator to send their graduate student to work with the AFOSR funded PI in the U.S. This program supports any funded country where it would mutually enhance research current efforts by sharing/learning new techniques and building lasting research partnerships.

FY21 Activity Summary



Research Area Funded by AFOSR-IO

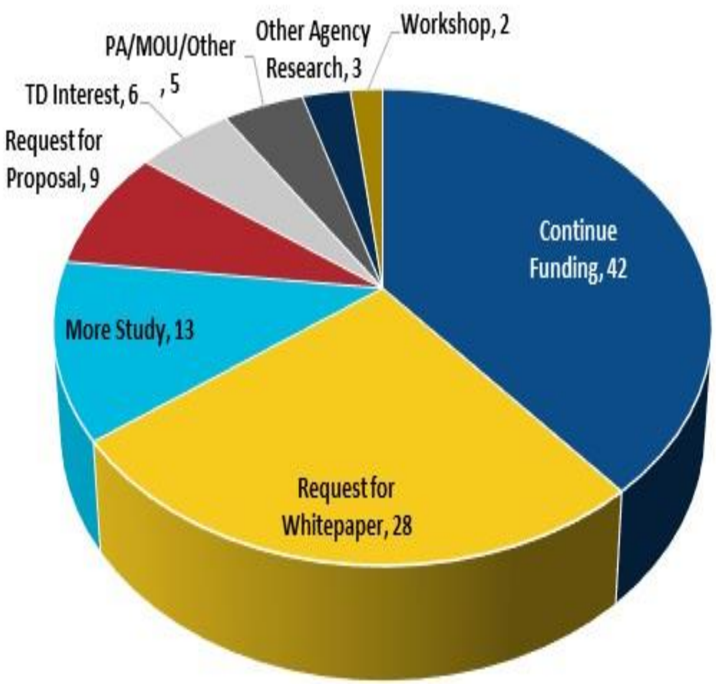


FY21 Tech Assessment

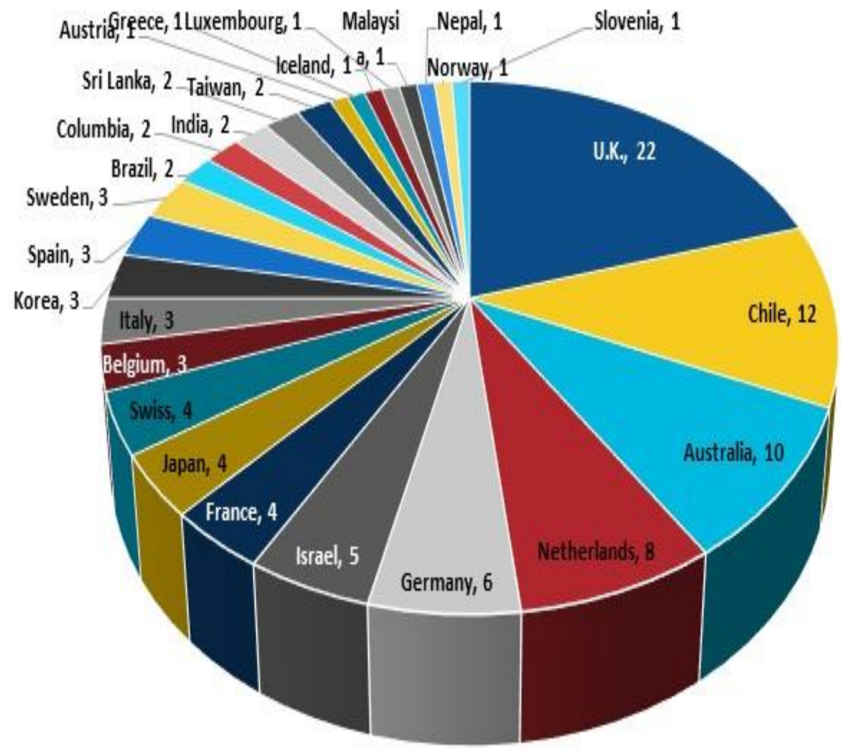
2021: 57 visits - 27 countries, 66 institutions, 108 assessments

2020: 75 visits - 29 countries, 114 institutions, 160 assessments

2019: 144 visits - 37 countries, 122 institutions, 167 assessments

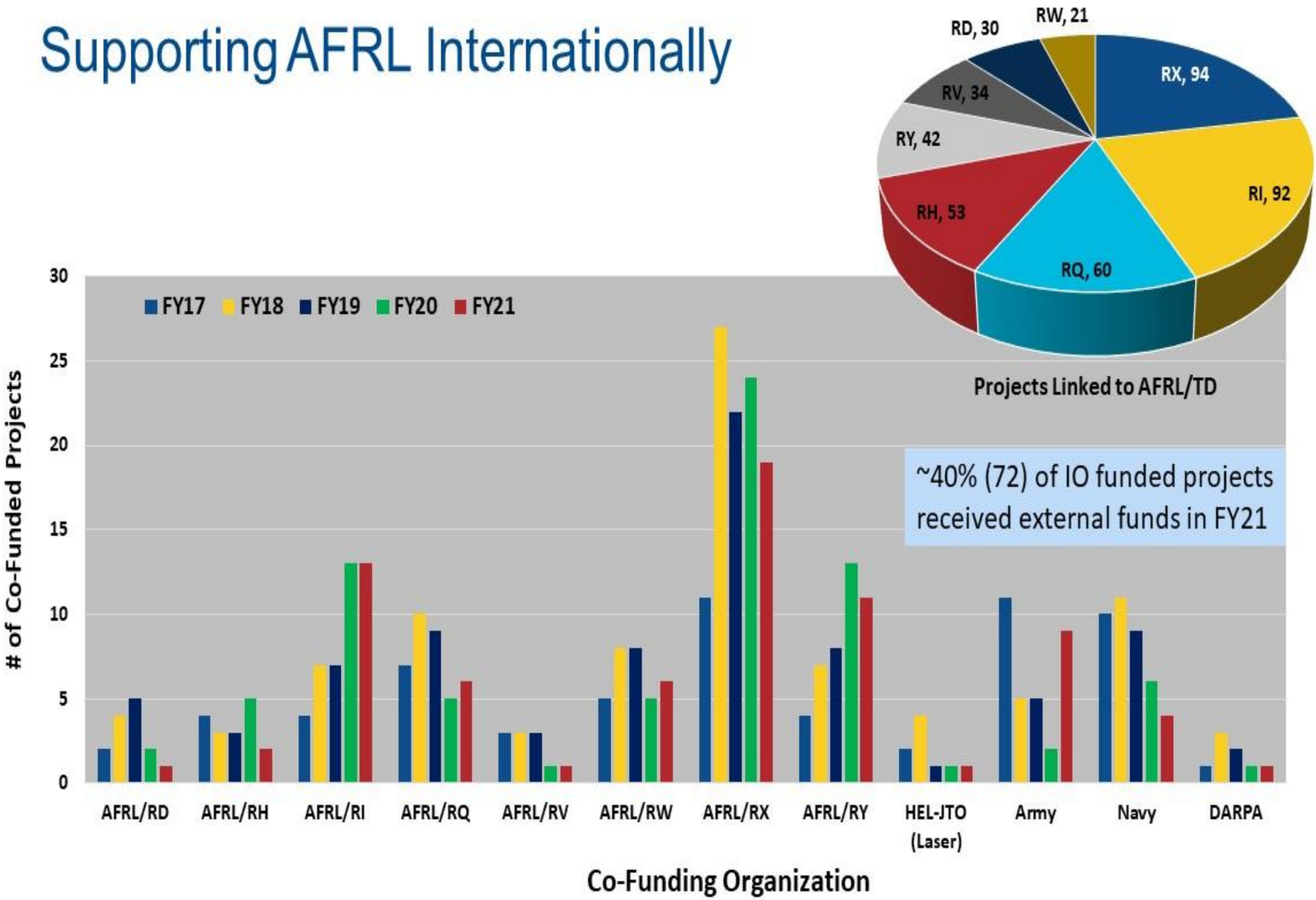


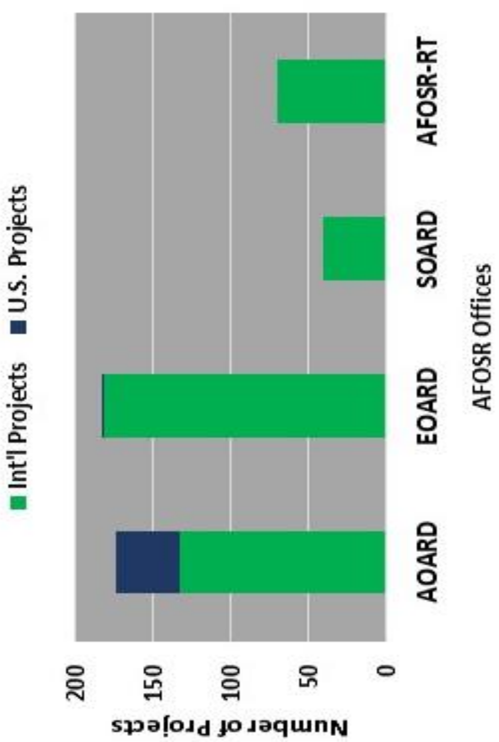
Recommendations

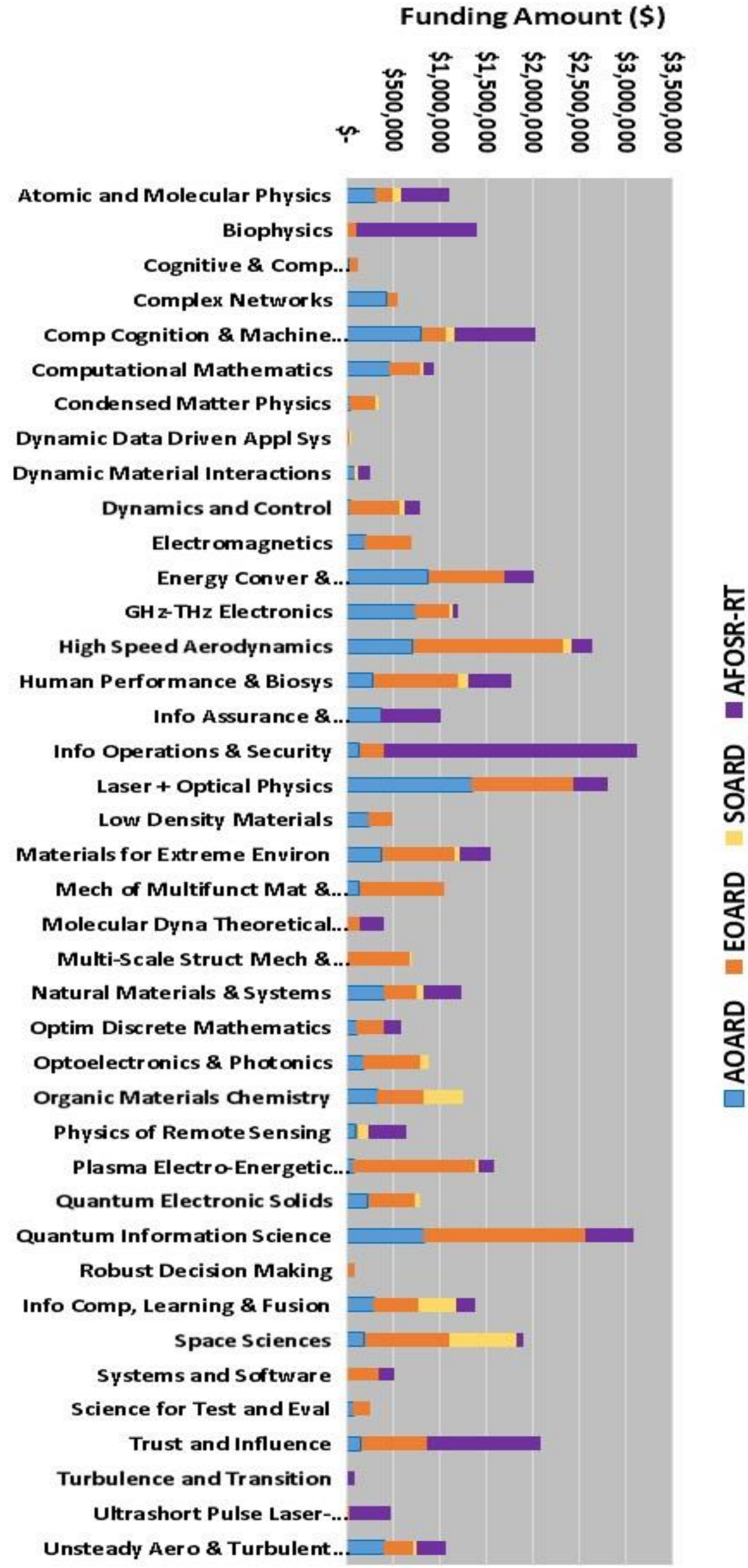


Number of Assessments

Supporting AFRL Internationally




Int'l Projects
U.S. Projects
Number of Projects
200
150
100
50
0
AOARD
EOARD
SOARD
AFOSR-RT
AFOSR Offices


Funding Amount ($)
$-
$500,000
$1,000,000
$1,500,000
$2,000,000
$2,500,000
$3,000,000
$3,500,000
Atomic and Molecular Physics
Biophysics
Cognitive & Comp...
Complex Networks
Comp Cognition & Machine...
Computational Mathematics
Condensed Matter Physics
Dynamic Data Driven Appl Sys
Dynamic Material Interactions
Dynamics and Control
Electromagnetics
Energy Conver &...
GHz-THz Electronics
High Speed Aerodynamics
Human Performance & Biosys
Info Assurance &...
Info Operations & Security
Laser + Optical Physics
Low Density Materials
Materials for Extreme Environ
Mech of Multifunct Mat &...
Molecular Dyna Theoretical...
Multi-Scale Struct Mech &...
Natural Materials & Systems
Optim Discrete Mathematics
Optoelectronics & Photonics
Organic Materials Chemistry
Physics of Remote Sensing
Plasma Electro-Energetic...
Quantum Electronic Solids
Quantum Information Science
Robust Decision Making
Info Comp, Learning & Fusion
Space Sciences
Systems and Software
Science for Test and Eval
Trust and Influence
Turbulence and Transition
Ultrashort Pulse Laser-...
Unsteady Aero & Turbulent...
AOARD
EOARD
SOARD
AFOSR-RT

Accomplishments by Country

ARGENTINA

The Role of Imperfect Interfaces on the Hereditary Thermomechanics of Microstructured Solids

The purpose of the project is to develop a multiscale constitutive framework that incorporates the role of imperfect interfaces on the hereditary thermomechanics of microstructured solids and that, at the same time, generates constitutive descriptions suitable for implementation into numerical codes for engineering structural analyses. The key idea envisaged by the project is to describe the thermomechanical behavior of the imperfect interfaces via a free energy density and a dissipation potential depending on reversible and irreversible displacement jumps and their rates, in accordance with the framework of generalized standard materials, to express the resulting field equations in variational form by combining the formulations of Hashin (1992) and Miehe (2002), and to derive approximate homogenized responses that depend on low-order statistics of the mechanical fields, including interfacial jumps, by suitably adapting order-reduction variational techniques (Lahellec & Suquet 2007, 2013). Because of the reduced number of effective internal variables involved, the resulting constitutive theories should constitute an adequate compromise between precision and simplicity.

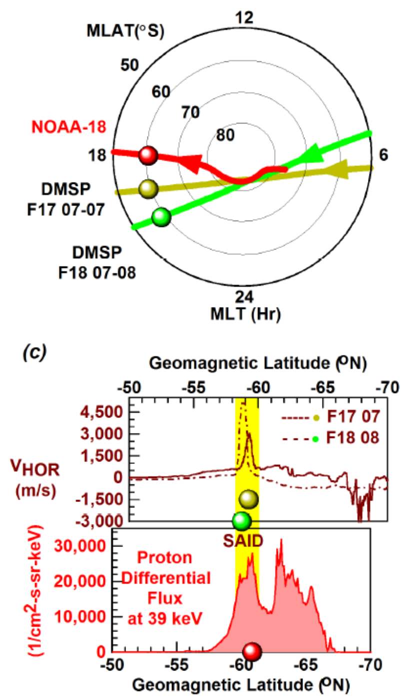
A great deal of progress has been made towards the development of the described computational framework resulting in 4 peer reviewed publications, assessment of the mathematical and theoretical structure of resulting approximations, and the development of 2 reduced order models that are currently being consolidated into one to produce a unified formulation that combines capabilities but eliminates limitations. This work includes collaborations with Laboratoire de M´ecanique et d'Acoustique in France and Los Alamos National Laboratory in the US.

AUSTRALIA

Electromagnetic Energy Deposition during Magnetosphere-Ionosphere-Thermosphere (M-I-T) and Investigating instability mechanisms and their impacts on the coupled Solar Wind-Magnetosphere-Ionosphere (SW-M-I) system

Prof. Iidiko Hovarth from the University of Queensland, Australia is actively working together with AFRL/RV in the solar wind (SW), Interplanetary Magnetic Field (IMF), and Interplanetary Electric Field (IEF) variations. The project has been extended to 2021-2023 as result of significant achievement in the research.

- The ionosphere has a critical impact on radio waves used for communications and GPS
- Geomagnetic storms impact coupled system
- Improved understanding of the ionosphere during geomagnetic storms helps predict and counter disruptions and outages
- Coordinating research with AFOSR MURI on geomagnetic storms
- Contributing to RV LRIR "Plasma Physics of the Subauroral Geospace Weather" that will replace current models
- Data analysis contradicts AMIE numerical simulation of energy deposition locations



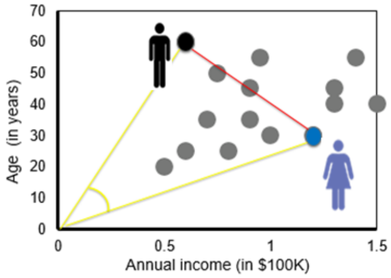
The close similarities found in the subauroral flows' development lead to the conclusion that the dawnside rapid subauroral flows are SAID flows developed on the dawnside.

Projects has been very successful, published 5 papers and 6th one is on the way this year in the Journal of Geophysical Research: Space Physics.

Program Officer: Dr. Tony Kim

Methods to Detect Outliers in Massive Datasets

From Deakin University, Dr. Sunil Aryal is investigating methods to detect outliers in massive datasets. Humans have an innate capability to identify items that stand apart from one or more groups, but to get computers to do the same, many issues complicate the process. The data types, (continuous, discrete, nominal, ordinal), the scaling metrics or the structuring (type, format) can all have a significant effect on the method or result. Dr. Aryal is developing a more universal method which is both robust and efficient. This work could have many applications from social engineering, image processing and space domain awareness. For the latter in particular, it is hoped that this work could aid in real-time identification of irregular satellite behavior by continual analysis of orbital tracking catalogues.



In conjunction with our South American office (SOARD) we have begun a new collaborative effort between Prof. Gibson of RMIT, Australia and Prof. Jero Maze of PUC, Chile. Together they are investigating nanoscale optical characterization of topological insulators which may be used for optical to electrical transducers. Meanwhile, in yet another project we are funding with the University of New South Wales, Prof. Bowen is analyzing HF data collected by the Australian Defense Science and Technology Group. This space weather program will improve regional and global models of the ionosphere which will, in turn, lead to better situational awareness for satellite and rocket operations and communications.

Professor Anand Veeraragavan from the University of Queensland reported on the first year's work on heated wall supersonic combustion testing. The objective of the project is to develop methods to heat test model walls within a tight temperature profile to enable their use in high speed wind tunnel tests including combustion. This year, the focus was on both generating computational simulations to determine appropriate wall temperature profiles and also exploring techniques for heating test models to desired conditions.

Conjugate heat transfer simulations were performed with UQ's chemical nonequilbrium shock tube calculation software NENZFID on a generic axisymmetric scramjet combustor. Computations were performed assuming both cold walls and walls at ambient 500 K. It was found that for the heated case, the combusting flow structure was significantly altered, inducing losses in the system. For this reason it is critical to carefully include wall heating in experimental testing of a scramjet combustor.

Once appropriate temperature profiles were established computationally, experimentation was performed on various methods of heating to determine how well they would work for future wind tunnel testing. The first method used cartridge heaters embedded in the test material to thermally conduct heat into the model. A number of different techniques were tested in a search for appropriate machining, power settings, vacuum settings, and heat transfer compounds. A second method to achieve higher wall temperatures was tested using a 20 kW inductive heating furnace. Early results indicate that temperatures exceeding 800 C will be achievable with this method.

Professor Andrew Neely and his team at the University of New South Wales continued work on investigation of hypersonic fluid-structure interaction. Collaborations with the University of Southern Queensland, Ohio State, Duke University, and North Carolina State University have contributed to the database of unit cases found at https://www.unsw.adfa.edu.au/high-speed-fsi-database-unit-cases. Progress was made on the moving shock and axial pressure gradient configurations from last year, concluding the PhD work of Sudhip Bhattrai. His computational and experimental analysis of fluid-structure interaction of a generic inlet showed 3D effects in the baseline configuration, and significant off-design results as deformation of the inlet ramp causes moving shockwave boundary layer interactions. Figure 2 shows the experimental model of the inlet with flexible ramp coated with speckles for digital image correlation.

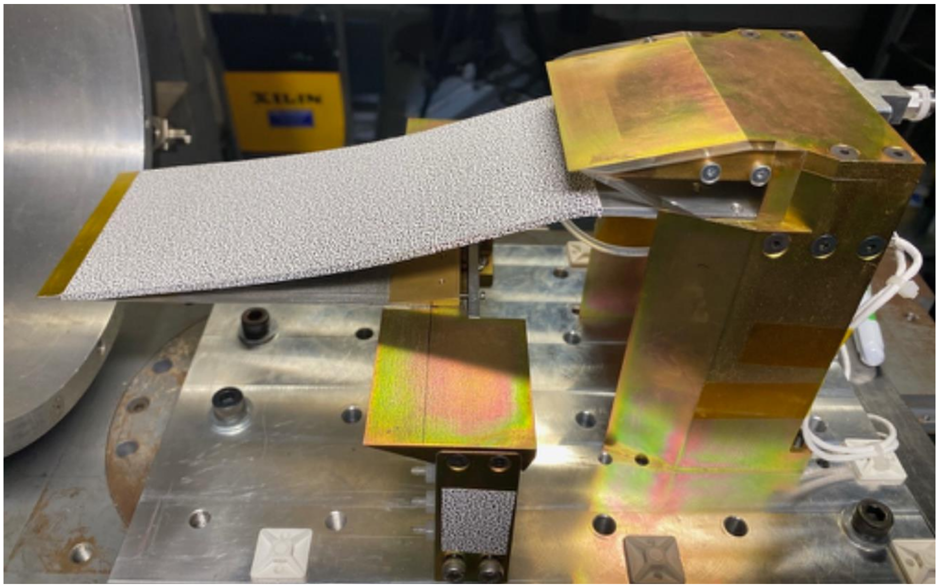
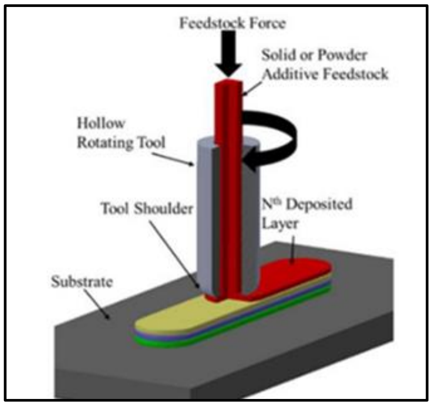


Figure 1. Inlet ramp with digital image correlation coating.

While access to the lab facilities has been hampered due to COVID-19 during much of 2020 – 2021, work is underway for next year on the hypersonic flutter, clamped panel, and even actuated wing cases.
Understanding Miniaturized Additive Friction Stir Deposition for Off-Earth Manufacturing

A new research project was started in FY21 with Prof. Daniel Fabijanic of Deakin University to study the limits and effects of miniaturization of the additive manufacturing technique additive friction stir deposition (AFSD) toward implementation in Space. The majority of in-Space additive manufacturing (ISAM) research effort to date has concentrated on polymer printing. However, polymer properties have limitations and the greater need is for high performance metal structural components and spares. Common powder/laser additive manufacturing technologies that work well on Earth cannot be translated readily to Space. This project proposes that AFSD is a feasible ISAM process for metals replacement parts, repair, and recycling. Some AFSD advantages are that it does not require powdered feedstock which can be difficult to manage in zero gravity, deposition occurs below the material melting temperature circumventing the gravitational effects on a melt pool, and dissimilar metals can be mixed that are not normally weldable or compatible. Uniquely, this metal additive manufacturing process operates without melting the input material, making it ideal for application in a zero gravity environment. For transport to and use in Space, the scale of the equipment and process needs to be greatly reduced, and the nonlinear scaling effects need to be understood fundamentally.



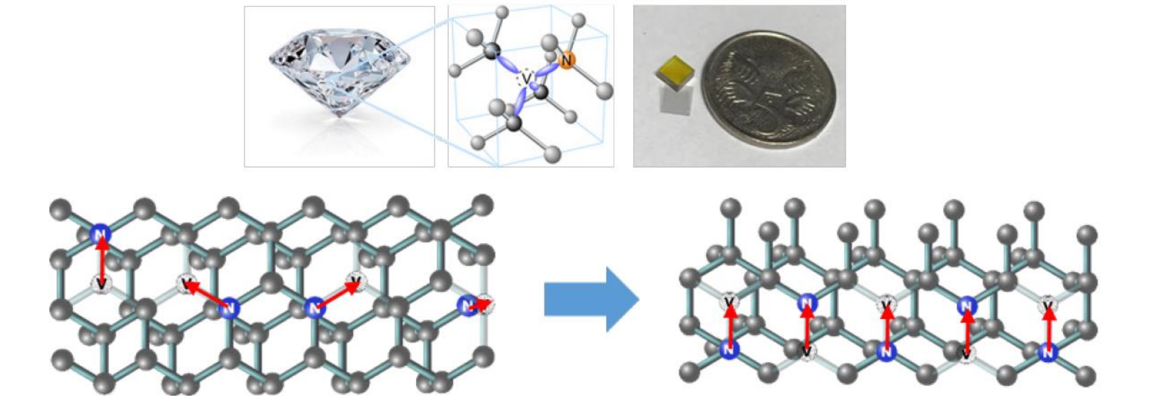
This project combines modelling and experimental research to establish deep process-structure-property relationships for micro-AFSD in bulk and repair deposits from aerospace aluminum alloys. The project objectives are to develop relationships between AFSD scale and process dynamic characteristics (force, torque, energy consumption) and the macro-scale quality of the deposition (porosity, degree of flashing), to develop deep process-microstructure-property relationships for aerospace aluminum alloys AFSD processed at various scales, and to understand the characteristics of the AFSD/substrate interface and relate to mechanical behavior. In addition to its relevance to the Space research mission, the outcomes will be widely applicable across DOD manufacturing endeavors toward deployable capabilities for repair and recycling of metal components.

Program Officer: Dr. Todd Rushing

Diamond-Based Magnetometers

David Simpson at the University of Melbourne in Australia has been systematically studying the production of NV ensembles in (111) diamond at the cutting-edge National Facility for Quantum Diamond at the University of Melbourne. His team aims to determine the optimal CVD growth parameters to achieve dense preferential alignment of NV defects in diamond over tens of microns for ultra-sensitive precision magnetometry. The team will characterize the magnetic field sensitivity of these novel materials using their world class quantum sensing laboratories and provide a direct comparison with (100) CVD diamonds grown in the same facility. This project will deliver critical new insights into the sensitivity limits of diamond-based magnetometers, and

Despite the extremely limited access to the diamond growth facilities throughout 2021, due to COVID restrictions, the team has conducted a series of diamond growths on nine (111) diamond substrates. The focus of the preliminary study was to identify the parameters which impact the diamond growth rate and surface morphology. The outcome from the initial series of growths suggests that low chamber pressure and low plasma temperatures appear optimal for smooth (111) diamond growth over several microns. The major outcome from this initial work is the production of Australia’s first ultrapure (111) diamond layers.



Engineering NV centres in diamond. Left, NV centres grown in four distinct orientations on (100) diamond substrates. Right, aligned NV centres grown on (111) substrates.

Decouple Non-Markovian Quantum Noise

Kavan Modi at Monash University along with **Charles Hill** at the University of Melbourne are working to decouple non-Markovian quantum noise. In the last five years Modi's group has developed a complete theoretical framework to overcome the challenges associated with the invasive nature of quantum measurements and can now describe any non-Markovian quantum noise in a straightforward manner. Their current project is concerned with translating this theory into experimental reality. They have made remarkable progress on this front in 2021 by characterizing noise on many of IBM's commercial-grade devices. Their achievements are possible by combining the theoretical prowess of the Monash group with hands-on experience with real quantum computers of the Melbourne group. Their first achievement was to characterize non-Markovian noise in real quantum computers. Several facets of this experiment that are noteworthy.

- Unlike most experiments reporting some non-Markovian phenomenon, they did not engineer the noise, i.e., these devices really are plagued with complex noise.
- Their experiment reports multitime quantum correlations. This has not bene achieved before. This is in contrast to all prior studies, which average the correlations over time. (Doing so makes it impossible to design better control over the device.)
- Their characterization outperforms the state-of-the-art tools like the gate set tomography.

Program Officer: Lt Col Michael Richards

Bio-Inspired Compliant Musculoskeletal Actuation for Miniature Robots

Dr. Ravi Sridhar from the University of New South Wales Canberra and Professor Mandyam Srinivasan from the University of Queensland in Australia were awarded a new start grant in 2021. Flying in real environments, that are densely cluttered with obstacles, is a major challenge limiting the proliferation of aerial robotic technology. Insects, in contrast, are capable of precise flight and navigation through cluttered terrain despite carrying only tiny sensory and motor systems. This project will systematically probe critical features of the action-perception loop within insects, to uncover the salient vision-based strategies that are used for guidance of flight in cluttered environments. PIs will address the behavioral adjustments and visuomotor strategies used by bees for spatial perception of static and dynamics obstacles, and navigation through various levels of clutter and spatial properties of the environment. While previous research has identified that insects use active vision strategies to extract environmental information, they are limited in our understanding of whether, and how insects tailor their flight maneuvers to extract spatial information in relation to clutter. The preparatory experiments for this project have revealed that bees' flight profiles can vary markedly between environments, and appear to rely on the properties of the spatial clutter. As illustrated in Figure, bees being presented with a single gap in a wall through which they were required to fly, they performed lateral peering movements to generate patterns of optic flow that would provide information on the width of the gap, and its traversability. Results from the biological experiments will be used to develop sensory and information processing frameworks for implementation in miniature robotic systems which will allow them to navigate autonomously in complex environments even when GPS positioning is denied. Such capabilities will expand the operational domain and potential applications for small autonomous vehicles while improving our knowledge of insect locomotion.

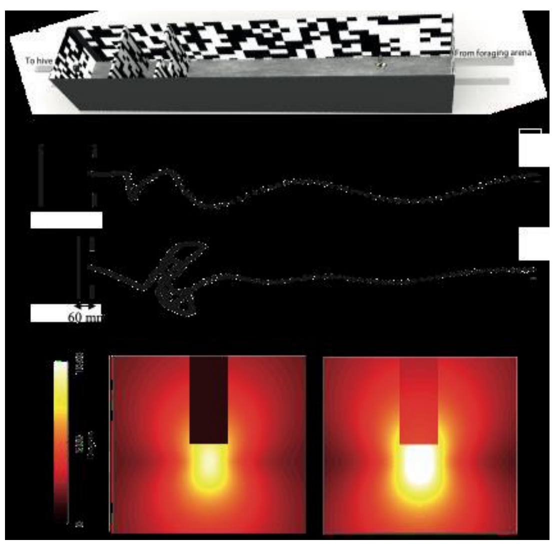


Figure (a) bee flying within a flight tunnel encountering a gap in the obstructing wall. (b,c) sample flight trajectory of a bee when the distance between the gap and background was is 300 and 60 mm. Mean optic flow on the obstructing wall derived from gaze recreation of the bees' trajectories.

Program Officer: Dr. Fumio Kojima

Austria

iBIAS: Harnessing the effects of algorithmic bias in online social networks

Dr. Gerardo Iñiguez, Co-PI: János Kertész – Central European University, Austria

In today's modern world people from different countries, ideologies and cultures share ideas through a pervasive and mostly hidden ecosystem of content filtering algorithms produced by companies such as Google, Twitter and Facebook that partially determine what information we see and share online. Despite the real danger of harmful influence and bias posed by the profit-driven filtering performed by these algorithms, little is publicly known about their proprietary components. The goal of this research is to assess the effect of algorithmic bias on society, such as information bottlenecks, echo chambers, and opinion radicalization, and derive heuristics to potentially correct the most harmful consequences of online bias.

During the first year of this effort, Dr. Iñiguez, Dr. Kertész and collaborators extended the theoretical description of binary-state dynamics of information spreading on online social networks, based on mean-field, pair and higher-order approximations. They introduced a simple but flexible notion of algorithmic bias with a single bias intensity parameter to measure the probability that the online platform filters out network neighbors with disagreeing opinions, thus preventing further interactions.

The potential and flexibility of the developed framework was demonstrated by applying it to three prototypical opinion dynamics: *the noisy voter model* where individuals copy the opinions of their neighbors, the *majority-vote model* where individuals change opinion if most of their neighbors have opposing views, and the *language model,* a non-linear extension of noisy voter dynamics which has a behavior interpolating between the *noisy voter* and the *majority-vote* model as a function of a model parameter.

Their initial research found that algorithmic bias promotes consensus in homogeneous networks, polarization of opinions in modular networks where pairwise interactions are predominant and coexistence of opinions when the dynamics are driven instead by group-based influence. The validity of the initial theoretical results were confirmed by performing numerical simulations of the dynamics on top of empirical network structures, confirming that the effect of algorithmic bias on the transitions between coexistence, consensus and polarization is qualitatively the same even in the presence of more involved structural features.

As the project advances the initial implementation of algorithmic bias will be extended with more realistic traits of current online media platforms, correlations between bias and individual traits, a combination of potentially competing filtering algorithms, and algorithms that react adaptively to changes in human behavior.

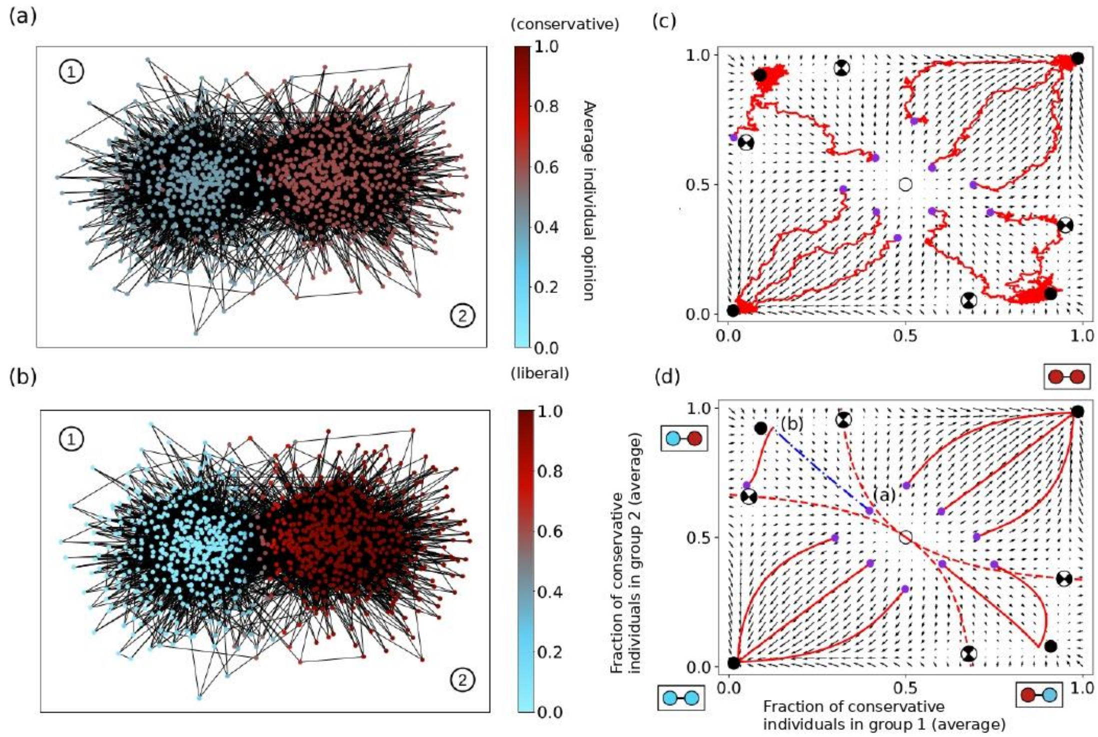
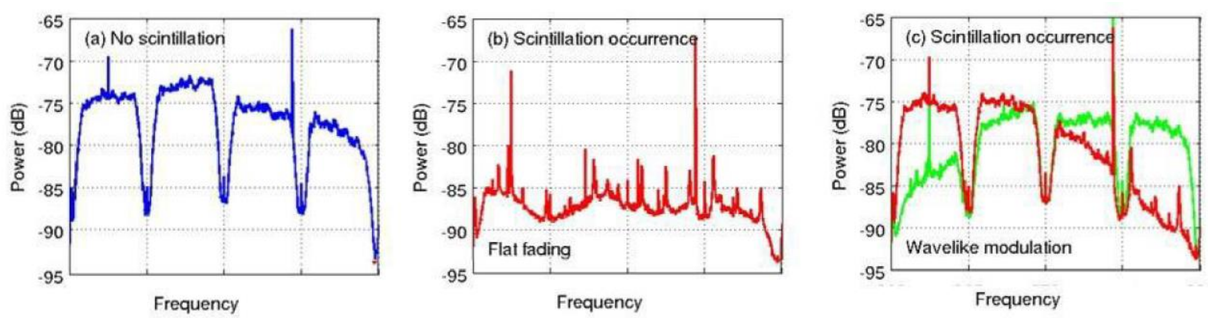


Figure 1: Simulations and approximations of opinion dynamics with algorithmic bias. (a-b) Numerical simulations of the noisy voter model with a basic implementation of algorithmic bias, on top of an empirical network linking liberal/conservative blogs during the 2004 US elections. Colors denote the average opinion of each individual in the initial (a) and final (b) states of the dynamics (liberal/conservative scale). As time goes by, the system becomes more polarized, until two emerging and opposite opinion groups coincide with the community structure underneath. **(c-d)** Schematic representation of the dynamics such that average trajectories evolve tangentially to an opinion vector field obtained from a mean-field approximation. Continuous lines denote dynamical trajectories in single numerical simulations (c) and in averages over realizations (d). The dashed line in (d) shows the trajectory from the initial condition in (a) towards the final state in (b). Small circles denote initial conditions; the rest are stable/unstable fixed points. Diagrams in the corners depict the majority opinions inside groups 1 and 2 in the corresponding areas of the vector field.

BRAZIL

Analysis of the Effects from Equatorial Plasma Bubbles Detected by the C/NOFS Planar Langmuir Probe on the Propagation of Transionospheric Wideband Signals

Equatorial plasma bubbles (EPBs) and ionospheric ion density irregularities exhibit extreme variability. The scale sizes that can be observed in these fluctuations vary over several orders of magnitude (from several hundred kilometers to less than one meter) and significantly degrade both the performance and the availability of space-based communication and navigation systems in different ways. For example, Figure 1 reproduces three power spectra resulting from wideband UHF (360-380 MHz) data received at Ascension Island during an observational campaign in October 2016. Different effects from the medium on the transionospheric wideband UHF signals were observed: (1) flat fading over the entire frequency band; and (2) frequency-selective fading, with the spectrum initially reduced at the lower-frequency sub-band (green curve) and then at the higher-frequency sub-band (red curve). The latter wave-like variation repeated itself quasiperiodically, with cycles of a few seconds. It is very difficult to interpret the observations of Figure 1 in terms of the immediately above results. It appears that a more detailed discussion based on different methods is needed to address why the existing models do not explain the observed features. The objective of the proposed work is to investigate how the large-scale EPBs, alone or in combination with the small-scale ion density irregularities that populate them, affect the propagation of transionospheric wideband signals in low-latitude and equatorial regions.



Spectra of transionospheric wideband UHF signals received at Ascension Island under different ionospheric conditions: (a) quiet, no perturbations; (b) perturbations causing flat fading across a 20-MHz band; and (c) perturbations causing frequency-selective fading across the same band at different time instants (green and red curves). (Courtesy of E. Costa)

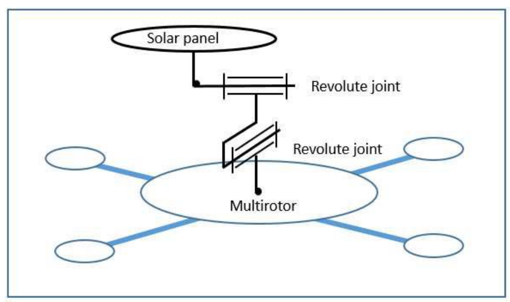
Laminar-Turbulent Transition Prediction on Three-Dimensional Wings

Laminar-turbulent transition prediction and control remain elusive objectives of the aerospace industry, despite decades of theoretical, numerical, experimental and flight-testing efforts aiming at understanding the physics of modal and non-modal linear mechanisms, and the nonlinear interaction of the most unstable disturbances that lead a laminar flow to transition and turbulence. In recent times, state-of-the-art analysis methods and numerical tools have been developed to interrogate flows with respect to their linear and nonlinear instability. In particular, progress with accurate and efficient computation of compressible laminar shock-dominated steady states enables global modal and nonmodal instability analysis of transonic, supersonic and hypersonic flows over or through arbitrarily complex geometries. A new project at University of Sao Paulo seeks to merge modern techniques. Work performed in Prof. Vassilis Theofilis, formerly of the University of Liverpool, has been focused on global instability theory, while Prof Leo Alves of the Fluminense Federal University has been developing tools to generate the appropriate instability free laminar steady states. Supported by AFOSR, both groups will collaborate closely to quantify linear instabilities and laminar-turbulent transition mechanisms in compressible flows. The research of the two groups has been supported by state-of-the-art shock-dominated steady laminar flow computations and the subsequent massively parallel numerical solution of complex non-symmetric eigenvalue and singular value problems, respectively governing linear modal and non-modal flow instability.

These developing efforts will address modal and non-modal global linear instability analysis and laminar-turbulent transition on aircraft wings in supersonic flight, in an integrated framework that includes airfoil-shape optimization from both the point of view of overall aerodynamic characteristics, as well as in terms of transition delay on the wing surface. Such improvements will make substantial contributions toward next-generation aircraft meeting ambitious environmental protection targets in terms of both reduced fuel consumption and noise mitigation.

CAMBODIA

Experimental study on control of UAV with Solar Tracker



Professor. Sarot SRANG, Department of Mechanical and Control Systems Engineering, Institute of Technology Cambodia (ITC), Phnom Penh, Cambodia is to investigation of flight dynamic and control for an Unmanned Aerial Vehicle (UAV) mounting a dual-axis solar tracker. Due to design complexity reason, in this project a multirotor and a serial dual-axis tracker will be used. The system is called multi rigid-body UAV. The control purpose is to have the tracker mechanism track the sun and the UAV flies simultaneously. During a flight, the rotation of the UAV changes the orientation of the mechanism. An embedded controller needs to move the actuators of the mechanism to keep tracking the sun. In this project two different objectives will be achieve, one is to control of the mechanism with movable support, and second is to build a prototype of UAV with solar tracker for testing. This project aims to study the net energy gain from a solar tracker on board and to investigate flight performance of a model-based controller for a multi rigid-body UAV. A prototype of the solar tracker and the multi rigid-body UAV will be built and experimented for model simulation validation. Program Officer: Dr. Tony Kim

CHILE

On the effectiveness of communication strategies as non-pharmaceutical interventions to tackle epidemics

Bernardin, Alejandro, Alejandro J. Martínez, and Tomas Perez-Acle. "On the effectiveness of communication strategies as non-pharmaceutical interventions to tackle epidemics." PloS one 16.10 (2021): e0257995.

When pharmaceutical interventions are unavailable to deal with an epidemic outbreak, adequate management of communication strategies can be critical to reducing the contagion risks. On the one hand, accessibility to trustworthy and timely information, while on the other, the adoption of preventive behaviors may be both crucial. However, despite the abundance of communication strategies, their effectiveness has been scarcely evaluated or merely circumscribed to the scrutiny of public affairs. To study the influence of communication strategies on the spreading dynamics of infectious disease, we implemented a susceptible-exposed-infected-removed-dead (SEIRD), epidemiological model, using an agent-based approach. Agents in our systems can obtain information modulating their behavior from two sources: (i) through the local interaction with other neighboring agents and (ii) from a central entity delivering information with a certain periodicity. In doing so, we highlight how global information delivered from a central entity can reduce the impact of infectious disease and how informing even a tiny fraction of the population has a remarkable impact compared to not informing the population at all.

Moreover, having a scheme of delivering daily messages makes a stark difference in reducing cases compared to the other evaluated strategies, denoting that daily delivery of information produces the most significant decrease in the number of cases. Furthermore, when the information spreading relies only on local interactions between agents, and no central entity takes action along with the dynamics, the epidemic spreading is virtually independent of the initial amount of informed agents. On top of that, we found that local communication plays an essential role in an intermediate regime where information coming from a central entity is scarce. As a whole, our results highlight the importance of proper communication strategies, both accurate and daily, to tackle epidemic outbreaks.

Convolved Spectra for Geosynchronous Satellites Characterization

Modern human life today relies heavily on an extensive network of satellites that perform critical activities such as communications (e.g., banking operations), navigation (e.g., GPS), atmospheric e.g., weather monitoring), and land surveillance, among others. Keeping this ever-growing network safe is undoubtedly strategic yet not easy as an increase in space debris has become a hazard. Consequently, the concept of Space Situational Awareness is an essential element for human civilization now and in the future. The Geosynchronous Earth Orbit Satellites (GEOS) are among the most critical satellites in this space network. On them depend some of the cornerstones of the modern world, like meteorology, communications, and national security. But despite their importance, very few systematic and continuous studies about their characterization and behavior in space have been made so far. The main difficulty in studying GEOS is its distance.

The geosynchronous belt is around 42 kilometers above sea level, making it impossible to resolve them, even to large aperture telescopes spatially. Meaning that the only way to study them is through unresolved optical techniques, such as their photometric light curves, the analysis of the color index of its reflected light, and the polarization of the light according to their position.

In this project, we will study the possibility of applying the convolved spectroscopy technique to identify and characterize geosynchronous satellites. The convolved spectroscopy technique consists of reconstructing the spectrum of any object in the sky based on the interpolation of data coming from the integrated obtained by broad and narrow-band photometry. The main goal of the project is to test the possibility of reconstructing the spectrum of multiple geosynchronous satellites using ground-based telescopes without the operational cost of spectroscopic observations. To do so, we will use the facilities available in the Falcon Telescope Network (FTN), a global array of small aperture optical telescopes designed to study artificial satellites and the nearby universe, and developed by the Center for Space Situational Awareness Research in the Department of Physics at the United States Air Force Academy (USAFA). One of the telescopes is installed in the north of Chile, three miles (5 km) away from Vicuña (the closest city) and 45 miles (72 km) to the west of La Serena, where the University of La Serena is located.

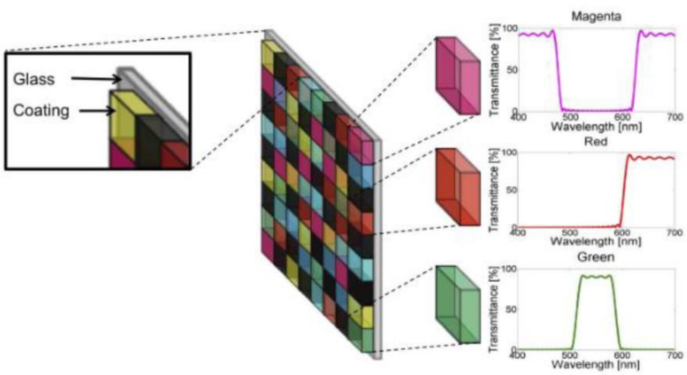
The FALCON Telescope install in Chile with the tubular structure and the German mounting system. (Courtesy of J. Nilo)

COLOMBIA

Infrared Color-coded Aperture Optimization for Object Tracking and Spectral Classification.

Compressive spectral imaging (CSI) acquires spectral and spatial information using less amount of data than the traditional scanning-based methods. CSI state-of-the-art has demonstrated that the color-coded aperture (CCA) design allows achieving improvements in the object tracking and spectral classification tasks in the compressive domain. However, it is essential to remark that most of the research is focused on the visible range of the electromagnetic spectrum, which is useless to the infrared spectral range because it does not consider some specific restrictions, for example, the sensor pixel size. Furthermore, conventional object tracking, and spectral classification approaches rely on universal spatial and spectral distributions to design the coded aperture masks, i.e., these approaches do not consider the available prior information about the materials' spectral data in the infrared spectrum. Therefore, designing and implementing a CCA considering statistical information in the infrared spectrum would greatly help to perform object tracking and spectral classification.

This project aims to mathematically design the spectral response and spatial structure of a color-coded aperture (CCA) in a compressive infrared imager based on a coded aperture optimization model, considering the predetermined prior target spectral information. Specifically, The CCA structure model exploits the target statistics, spectral behavior, and physical considerations of the compressive infrared systems, which result in improvements in object tracking and spectral classification. At the same time, this approach increases the framerate and reduces the computational complexity and data storage costs of the system. The main novelty of this proposal is introducing the CCA optimization concept for object tracking and spectral classification in the infrared domain, where additional considerations about the propagation phenomena and prior target spectral information need to be included.



Colored coded aperture pattern is illustrated. Each pixel on the coded aperture is one of many possible optical filters whose spectral response can be selected. (Courtesy of H. Arguello)

COSTA RICA

Investigating energy transfer phenomena in novel organometallic nanomaterials and metal-binding biomacromolecules using electrode nanogap-enabled, dielectrophoresis-assisted electronic and spectroscopic measurements

Various techniques have been deployed to visualize nanoscale phenomena and interactions occurring inside on-chip devices, such as light microscopies and spectroscopies. Recently, a number of studies employed a combination of such optical techniques with nanoelectronic techniques for the detection of nanomaterials, thus advancing understanding of the associated physical, electrochemical and structural information. Nanogaps between electrodes less than 10 nm fabricated in a simple microfluidic device and assisted by electrokinetic methods of molecular manipulation using dielectrophoresis in combination with Surface Enhanced Raman Spectroscopy (SERS) and electronic detection techniques were reported by the PIs to trap and sense the presence of biomacromolecules, oligomers, and protofibrils in a solution, which provide detailed spectroscopic information of the samples down to the low-copy number level. Exploring Fluorescence Correlation Spectroscopy method to analyze the fluctuations of the electronic signals obtained during the trapping of biomacromolecules in the nanogaps, reveal characteristic autocorrelation curves and relevant physical data. Apart from the optical and spectroscopic measurements, signals related to electronic conduction are obtained, which can only be enabled by positioning the nanomaterials in the nanogap. These signals are characterized to have very low current level (pA range) and a fluctuation spectrum, with an r.m.s. value characteristic for each energy conductance level, which may present a great opportunity to probe the conduction phenomena across nanomaterials, thus shedding light on the fundamental energy transfer processes at the low-copy number/single particle level. The novel chip platform of electrode nanogaps are posited become a new nanomaterial analysis technique compatible with various samples of interest.

This first-funded effort in Costa Rica is TriService supported with investigators in Costa Rica, Taiwan and a strong AFRL/RX connection (biomaterial portion). The project consists of studying the behavior of novel germanium-based organometallic compounds (GeOMC) and rare earth metal-binding biomaterials, using the novel dielectrophoresis-assisted electrode nanogap platform and its variations for electronic and spectroscopic detection (US Patent 9915614 B2, 2018), down to the low-copy number nanoparticle/biomacromolecule level. The opto-electronic properties of nanoparticles made of these materials will be characterized while trapped across an electrode nanogap, in both “dark state” and photoexcitation conditions and subjected to local variations of a bias electric field. In addition, there will be a similar study of the binding of lanthanide (Ln) ions to LanM proteins trapped between the nanogap electrodes in order to experimentally understand the subsequent conformational changes that these proteins undergo, through electrical conduction and simultaneous SERS. The insight gained from this investigation could be instrumental in shedding light on the fundamental processes of energy transfer in novel hole transporting materials. This could help establish perovskite solar cells as alternative, clean, and renewable technologies while opening up new applications with LanM protein-based biotechnologies for detecting, sequestering, and separating technologically important lanthanide elements.

ECUADOR

Mitochondrial transfer from melanocytes to cells: the discovery of a new process

Cells have evolved mechanisms to interact with, minimize, and recover from harm through their mitochondria. These mechanisms are associated with intracellular and mitochondria protection by the activation of damage signalization pathways. Recently, it was observed that many cells could share their mitochondria with others that are damaged to induce repair. The skin is a complex tissue were different cell types interact to maintain homeostasis. Evidence has shown that skin cells protect themselves from harm; however, it is yet to be understood how cells interact with themselves or, among other types, preserve their function or recover from damage. In preview studies, the PI's group has observed that mesenchymal stem cells (MSCs) transfer their mitochondria to other cells when harmed or stressed, including to immune cells and cancer. This process repairs the loss of function in mitochondrial recipient cells and provides an increased ATP production, proliferation, migration, and possibly stress resistance or repair. Interestingly, melanocytes produce cellular connections and microvesicles secreted towards the keratinocytes, similarly to what is observed with MSCs and harmed or damaged cells. Using in vitro approaches such as cell culture, microscopy, and molecular biology, this project aims to discover if melanocytes can transfer mitochondria to other cells in the skin, in the same way as MSCs. This proof of concept will provide a new understanding of a biological mechanism regarding mitochondrial intercellular cell repair.

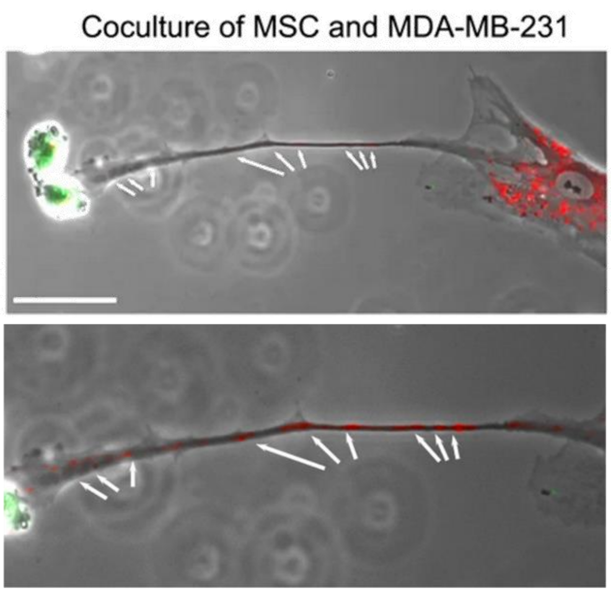


Image from Caicedo et al., 2015 showing how MSCs labeled with MitoTracker Red are connected to cancer by nanotubes and transferring mitochondria, red dots indicated by white arrows. https://www.nature.com/articles/srep09073

FRANCE

Multiscale materials science: a mathematical approach to defects
Dr. Claude Le Bris and Dr. Frédéric Legoll
Ecole Nationale Des Ponts Et Chaussees

Dr. Claude Le Bris and Dr. Frédéric Legoll's research focuses on the theoretical and numerical aspects of equations required for the understanding, modeling, simulating and control of real materials with the imperfections not addressed by current theories, which assume ideal perfect materials.

In previous research, the team focused on the diffusion equation and successfully developed an alternative pathway to standard homogenization techniques by combining a fine scale description of the heterogeneous medium with a highly oscillatory coefficient with an effective description modeled by a constant coefficient. In the limit of asymptotically infinitely fine structures, the developed approach yields the value of the homogenized coefficient.

The current research focus is the consideration of a multiscale advection-diffusion problem, in a convection-dominated regime such as with the Navier-Stokes equation in perforated media. There are two small scales in the problem. The first small scale is the small characteristic length of the diffusion coefficient throughout the domain. The second small scale is due to thin boundary layers in the convection-dominated regime.

In addition to the difficulty caused by the presence of different scales, the strong convection is also a source of potential instabilities in the bulk of the domain. Taken separately, each phenomenon can be addressed by classical approaches such as Multiscale Finite Element Methods and stabilized type techniques, respectively. Dr. LeBris and Dr. Legoll are researching how to adapt the two methods to create a single unified approach to efficiently solve multiscale advection-diffusion problems in the convection-dominated regime. The key objective is not to capture the small-scale features of the solution (its small oscillations in the case of a multiscale purely diffusive problem, or its value in the thin boundary layer), but rather to accurately capture the effects of these small-scale features on the coarse-scale solution.

Landscapes of large-scale problems with applications to machine learning
Professor Jérôme Bolte and Professor Edouard Pauwels
Université de Toulouse, France

Neural networks are ubiquitous in machine learning and artificial intelligence applications such as image recognition, navigation or language processing. Professor Jérôme Bolte, Professor Edouard Pauwels and their research team develop mathematical theory to improve and create neural network algorithms. A central aspect to their work is the consolidation of their theory on nonsmooth automatic differentiation towards more guarantees and further stability and robustness results.

In view of training increasingly complex learning architectures, Professor Bolte and Professor Pauwels established a non-smooth implicit function theorem with an operational calculus. This result applies to most practical problems provided that a non-smooth form of the classical invertibility condition is fulfilled. This approach allows for formal subdifferentiation, or ``formal propagation of derivatives", and is fully compatible with algorithmic differentiation such as backpropagation used in the training of Neural Networks. This allows them to provide the first known guarantees in the training of nonsmooth model selection problems, MONDEQs, but also differentiable programming problems.

The team leveraged the semi-algebraic representation of the ReLU function to describe the input-output relation of monotone Deep Equilibrium networks (MONDEQ) using a polynomial system. This constitutes the first general approach for certification of implicit networks of this type. This work published at NeurIPS already seems to have a significant impact.

In their most recent research, they also developed a new methodology for the analysis of the dynamics of first-order algorithms with vanishing step size and demonstrated its phenomena in the training through first-order methods: transverse oscillation compensation in conjunction with a slowdown along the main progress direction, and criticality of the limiting process. The core paper is accepted in the prestigious JEMS. This approach has been and is being generalized to several algorithms and frameworks.

INDIA

Professor Subramanyam Duvuuri at the Indian Institute of Science in Bengaluru was awarded a new start grant in 2021. His team will develop an ultra-miniature shear stress sensor for use in studying boundary layer physics in both low and high-speed flows. By teaming with his collaborator in the nano-fabrication laboratory he will be able to rapidly design and test sensor geometries and materials to enable non-intrusive, highly accurate measurements of shear stress. This new diagnostic tool may reveal insight into how boundary layers develop, leading to more efficient vehicle designs.

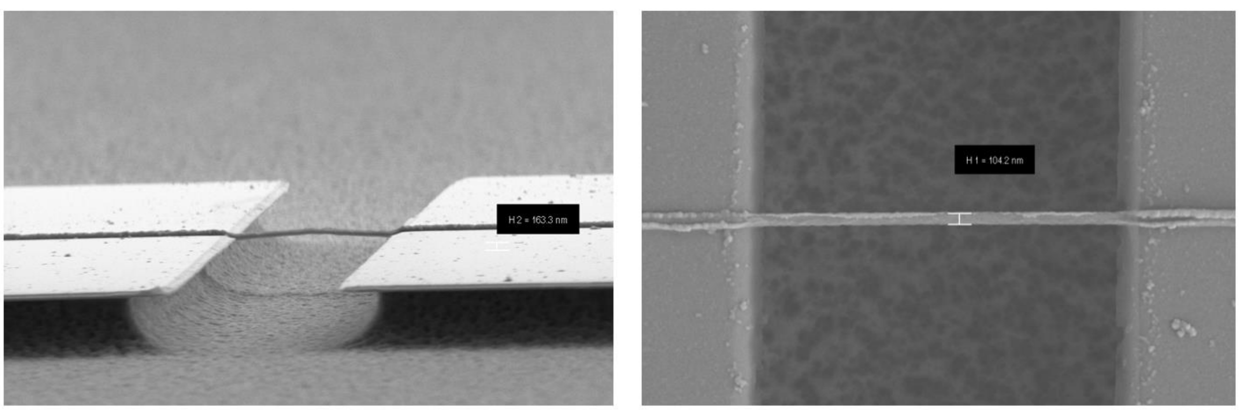


Figure 2. Scanning Electron Microscope images of a platinum filament nano-heater developed at IISC using nano-fabrication techniques similar to those proposed in the new start grant.

Integrating Organic Quantum Dots into Covalent Organic Frameworks to make Lightweight, Flexible, Conducting Polymers

Starting in FY21 Prof. Vaidhyanathan Ramanathan of the Indian Institute of Science Education and Research (IISER), Pune, India is leading a basic study into nanocomposites of polymeric covalent organic framework (COF) materials and organic quantum dots. The project is a targeted and simulation-guided effort to use the unique properties of quantum dots to encourage electrical conductivity in COF thin films by embedding quantum dots into structural sites, interlayer spaces, and nanopores. The goal is to achieve a by-design electronically and ionically conducting flexible material by minimizing the pi-stacking defects in COF structures to create well-ordered structures with high porosity and surface area. The effort looks to use synthetic quantum dots in the form of embedded "conjugation patches" or covalently linked "conjugation bridges" between layers of COFs to enhance electronic and electrochemical properties. The performance goal for the nanocomposites is improving electronic conductivity to a value of at least 0.1 S/cm in an all-organic lightweight material. Improved understanding of the underlying relationships among the processing conditions, resulting nanostructures, and physical properties of the materials could lead to applications such as textile-integrated electronics and electrochemical devices.

Ireland

Over the last decade, we have vastly improved understanding of the factors shaping the gut microbiome and has revealed a broad scope of influence of the gut microbiome on brain function and behavior (Cryan et al., 2019). This includes an impact on stress-related behaviors such as depression and anxiety, neurobiological signatures including neuro-inflammation and fundamental aspects of CNS structure such as the integrity of the blood brain barrier (Fulling et al., 2019). However, these studies have been largely preclinical but there still lacks any sort of proven health and performance-related benefit. Professor John Cryan and Gerard Clarke (University College Cork) are currently exploring ways to advance the mechanistic understanding of gut-brain interactions so that we can pave a way forward for the development of actual countermeasures for stress-related disorders, which would be hugely beneficial to airmen in operational scenarios. The project aims to determine the role of the microbial metabolites in these host-microbe interaction. The researchers have identified candidate metabolites for assessment, based on both literature search and metabolomics analysis in mice following acute restraint stress. The microbial metabolites of interest comprise short-chain fatty acids, tryptophan metabolites, primary and secondary bile acids and microbially-related xenobiotics. In addition, they have begun assessing the effects of these metabolites on gut and blood-brain barrier function in *in vitro* models. Their research indicates that short-chain fatty acids butyrate and propionate confer protective effects at both the gut and blood-brain barriers, but further work is required to determine if these compounds confer their benefits through similar mechanisms at both barriers, and to confirm that these effects can ameliorate the adverse impact of stress exposure on these barriers *in vivo*. Furthermore the researchers, have identified microbially regulated circadian rhythms of gut barrier function. Future work will evaluate the implications of these observations for the role of microbial metabolites in regulation of barrier function in the gut and the brain.

Israel

Integrated Guidance and Weapon Target Assignment for Swarm Engagements

Professor Tal Shima, Aerospace Engineering Technion - Israel Institute of Technology

Professor Tal Shima and his team research the development of new algorithms and guidance concepts for teams of interceptors in swarm-on-swarm engagements. One of the outstanding problems they consider related to cooperative guidance is that of coordinated attack in which a group of interceptors tries to arrive at the same target at the same time, or at carefully planned moments of time. The problem was considered from the point of view of an interceptor team and concentrated on the mid-course and end-game stages of engagements assuming perfect information on the states of the participants.

The first direction of research consisted in devising geometric guidance rules that allow for efficient coordination between a possibly large numbers of coordinating interceptors. Using the tools of cyclic and leader-follower information exchange frameworks the methods developed by the team allow simultaneous target interception at the minimum possible time and any desired impact time greater than the minimum, respectively. They proved that the impact time of each pursuer is guaranteed to converge to the maximum impact time among the pursuers in the case that they are heading straight to the target, resulting in a situation that is called max-consensus. For the case of desired impact time, the leader imposes the desired impact time independent of the other pursuers in the system, and the followers modify their impact times according to that of the leader, eventually leading to simultaneous interception. It was shown that the developed concepts can be implemented using a simple Proportional Integral controller achieving simultaneous interception from arbitrary initial positions of the pursuers.

A second research direction focused on deriving an optimal guidance law to achieve a desired impact time while optimizing a quadratic guidance effort criterion. To this end, the team developed a solution to the problem of minimum integral guidance effort control for an approximate second-order kinematic vehicle. The advantage of using approximate second-order kinematics is that this approach allows the development of "analytic" solutions based on simple algebraic computations and one-dimensional look-up tables that can be realistically implemented on a guidance computer. Additionally, the team's developed solution not only provides accurate estimates of the optimal guidance effort but also the maximum lateral acceleration necessary to realize it. These estimates are important to obtaining effective many-on-many intercept guidance strategies, as they allow for solving complicated weapon target allocation problems while taking into account the guidance performance of underlying interceptors and their individual limitations in terms of maximum lateral acceleration.

These research results were recently published in the AIAA Journal of Guidance, Control, and Dynamics.

Tailoring Heterogeneous Effects for Optimizing Response of Emerging and Extreme Environment Materials (THEORE3M)

The THEORE3M program develops from a recent series of WOS visits to AFRL/RX from Israel and Spain. THEOREM is a joint effort between AFOSR Arlington, EOARD London, and AFRL/RXC, Israel Institute of Technology, Technion, Haifa, Israel (Prof. Daniel Rittel), and Universidad Carlos III, Madrid, Spain (Prof. Jose Antonio Rodriguez-Martinez) – an excellent example of “combined arms integration.” The effort concluded its first year. Accomplished were the creation of new ballistic testing capabilities at the Universidad Carlos III for assessing the fragmentation response of materials, and novel specimen testing for a high strength Air Force steel at the Technion. New models describing defects in printed and wrought materials under dynamic loading were constructed via the international team collaboration. Brand new interferometric instrumentation was acquired and fielded to perform time-resolved *in-situ* measurements of the shock compression process. Novel shear compression specimens (SCS) developed for AF9628 provided a first-time mechanistic understanding of the instability-driven processes that lead to dynamic fracture and fragmentation. The team begins its second year rounding-out the test campaigns, beginning the ring expansion tests (Spain) for fragmentation assessment, and building a comparative study of the meso-scale models created by Prof Rodriguez-Martinez with existing models of dynamic fracture developed at AFRL/RX. The team will also organize a symposium at the International Conference on Plasticity in the area of meso-scale modeling and microstructural effects on dynamic plasticity and failure.

AFRL Technical PI and POC – Dr. Manny Gonzales

ITALY

Design criteria and prediction tool based on a Multi-parameters analysis of Pulsating Heat Pipes.

Principal Investigator: Prof. Sauro Filippeschi, University of Pisa
Program Officer: Maj Grant Thomas, EOARD, Space Science

Motivation
Successful thermal management of components is a key issue for spacecraft where the design of compact, light, sustainable, reliable and efficient heat transfer devices is desired. Spaceraft undergo varying operating conditions that make thermal management challenging such as variable acceleration fields from microgravity to hyper-gravity, extreme heat loads and temperatures, as well as the vacuum of space. The last three decades of the 20th century witnessed the spread of heat pipes, both grooved and sintered, as the leading thermal technology in the field. However, from the beginning of the 21th century, a new type of wickless two phase passive device, known to the most as "Pulsating Heat Pipe" (PHP) or "Oscillating Heat Pipe" (OHP), has emerged to fulfill the aforementioned technological requirements while adding the adaptability to three dimensional surfaces, possibility to be embedded in advanced materials, and even to be foldable. The simple structure of such a device is a capillary closed loop which is characterized by complex thermofluidic behavior which is still not fully understood. This ambiguity hinders the reliability of the modeling tools and, consequently, the confidence in the design process. Systematic studies to develop robust prediction tools are desired. After 10 years of continuous research on PHPs this research group will evaluate a general multi-parametrical experiment that aims at mapping the device behavior on the widest working range ever achieved and systematically investigate the device start-up and dry-out processes. A single apparatus allows to perform both fluid high-speed visualization and fluid pressure and temperature mapping in several locations other than the classical parameters that are often investigated.

The objective of this research is to develop a predictive physical model of pulsating heat pipes that can be used for a preliminary design and to determine the working limits of the technology. The research team will develop a validation-oriented experimental test that will allow researchers to dynamically investigate the thermocapillary phenomena in the evaporator section. The researchers will also develop techniques to provide accurate and repeatable measurements of heat fluxes, temperatures, and pressures in the tube wall and fluid, allowing the detailed exploration of the flow pattern and phase velocity. A successful model will enable researchers to push the limits of PHP technology for optimized spacecraft thermal management.

KOREA

Chiroptical Organic Semiconductor/Chiral Molecule Hybrid Thin-Films via Chirality Transfer Phenomenon

Dr. Jung Ah Lim, Principal Research Scientist at the Center for Opto-Electronic Materials and Devices, Post-Silicon Semiconductor Institute, Korea Institute of Science and Technology (KIST) initiated basic research in FY21 to investigate the sensitivity and tunability of a method of selectively combining two organic materials to create a composition that retains the desirable properties of both materials while overcoming property limitations of the individual components. The intent is to use chiral, functional, small molecules to impart chiroptical character to thin films primarily comprising and having the structural advantages of achiral polymer semiconductors. The approach is to use a known semi-conducting polymer, poly(3-alkylthiophene), as a matrix material and to incorporate chiroptical small molecules derived from 1,1,-binaphyl into blends. The dependency of chiral transfer and film morphology on molecular interactions will be studied by varying functional group characteristics. Variables will be analyzed such as degree of functionalization to tune hydrogen bonding and polymer side chain length. In addition to other characterization methods, the photophysical chirality transfer mechanism will be studied by analyzing the photoluminescence-excitation mapping of the hybrid system. Better understanding of the structure-property relationships can help enable a materials by design pathway for optoelectronic devices using the studied materials. Provided that desired photophysical performance can be attained and controlled, a potential advantage of the proposed blending approach compared with other studies into liquid crystal and chiral semiconducting polymer systems is that the creation of robust films could be relatively simple, scalable, and implementable for the industrial production of optoelectronic devices. Tailorable chiroptical and optoelectronic materials have applications for sensing and communication technologies where detection, absorbance, emittance, and conversion of light are desirable.

Program Officer: Dr. Todd Rushing

Foundational Aspects of Machine Learning in Multi-Agent Online Games as Serious Games
PI: Director Sungwon Yi (PhD), Electronics and Telecommunications Research Institute

This seedling project investigated research issues in multi-agent systems, emanating from complexity of real-time systems, such as DOTA2 (Defense of the Ancients 2). To scale the problem for this project size and duration, the research team focused on a simpler Dota-Client, and extended it to support multi-agent gameplay and implemented the QMIX multi-agent reinforcement learning (MARL). The code can be found at https://github.com/etri/dotaclientQMIX. In addition, the project produced two patent submissions and two conference papers. The project was co-funded with support from ONRG. The research team collaborated with another AFOSR-funded PI from Penn State under the Dynamic Data and Information Processing program.
Program Officer: Lt Col Alan Lin, USSF

Classification Attack Detection via Class Visual Context Discrepancy Measure
Associate Professor Hyun Oh Song, Seoul National University
This two-year project investigates the vulnerability of deep learning models to adversarial inputs and proposes a novel, optimization based detection method that is resistant to the gradient-based adaptive attacks by construction. Experimentation will use the ImageNet dataset to measure the efficacy of discriminating adversarial inputs. The first year of the effort resulted in an accepted paper at NeurIPS21 and an accepted paper at AAAI22. This project was co-funded with support from ONRG. Program Officer: Lt Col Alan Lin, USSF

Cyber Physical Analysis of System Software Survivability by Stimulating Sensors on Drones
Director Yongdae Kim (PhD), Korea Advanced Institute of Science and Technology

The goal of this project is to develop a framework to determine the system margin of drone control system against sensor-spoofing attacks, in both simulated and hardware-in-the-loop experiments. While drone manufacturers conduct safety checks to guarantee controller real-time performance, there are fewer checks on the security, which may be problematic in drones that leverage multiple, low-cost sensors. The first year's experimentation focused on gyroscopes under laboratory conditions. Future work will incorporate accelerometers and more real-world settings. Program Officer: Lt Col Alan Lin, USSF

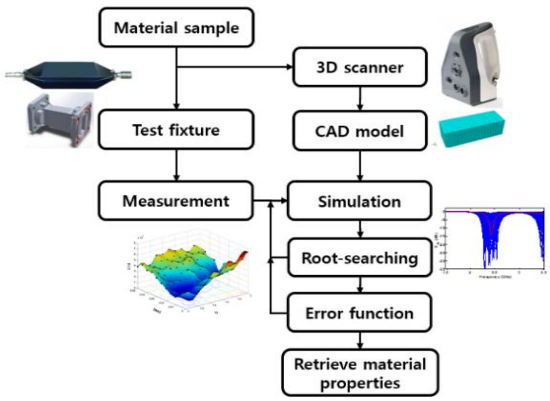
Data-Driven Multiscale Damage Prediction Simulator for Recyclable Themoset (Vitrimer) Nanocomposites

Prof. Gunjin Yun and his research team at Seoul National University made significant basic research progress in FY21 toward the development of a data-driven multiscale damage theory and simulator for vitrimer nanocomposites based on a polymer physics-based constitutive model. Experimental work was conducted on self-healable vitrimer nanocomposites composed of epoxy resin and incorporating aromatic disulfide dynamic bonds as an associative crosslink exchange mechanism. The team is studying various resins and disulfides to investigate the effects of crosslink density and crystallinity and including carbon nanotubes to enhance mechanical strength and facilitate self-healing due to their high thermal conductivity. The research seeks to reveal the relation between self-healing efficiency and multifunctional vitrimers with various stiffness values. With Tg below room temperature, catalyst-free S-vitrimers offer the potential for self-healing at room temperature without any external stimuli due to aromatic disulfide exchange reaction and hydrogen bonding. In addition to the experiments, the researchers are developing a polymer-physics-based multiscale model for the vitrimer nanocomposites. The research approach involves a combination of a polymer-physics-based constitutive model, micromorphic representative volume elements that capture nanoscale filler effects, deep-learning algorithms, imaging of real nanocomposite specimens, and in-situ SEM tensile experiments for model verification. A fundamental understanding of damage mechanisms and the ability to simulate the response reliably will be a valuable contribution for the design of vitrimer matrix composites.

Program Officer: Dr. Todd Rushing

Project: Development of a Broadband Material Characterization Technique Robust to Sample Preparation and Calibration Errors

Professor. Jae-Young Chung, Principal Investigator from the Electrical & Information Engineering department, Seoul Technology University of Korea is to determine the optimal computational solution and root-searching algorithm. Some of the technical objectives are to; design the optimal broadband test fixture and fabricate a prototype, conduct measurements on various material samples to validate the proposed approach, and Implement an autonomous data acquisition & post-processing macro code.   Professor. Chung utilized Electromagnetic Measurement & Application (EMMA) laboratory in Seoul Tech and collaborated test results and models with AFRL/RYM.



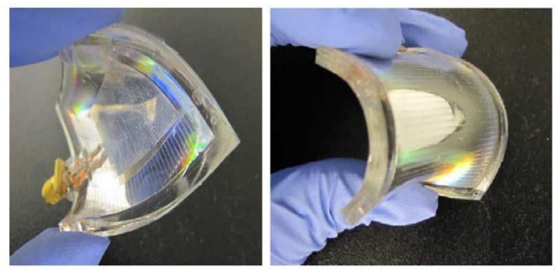


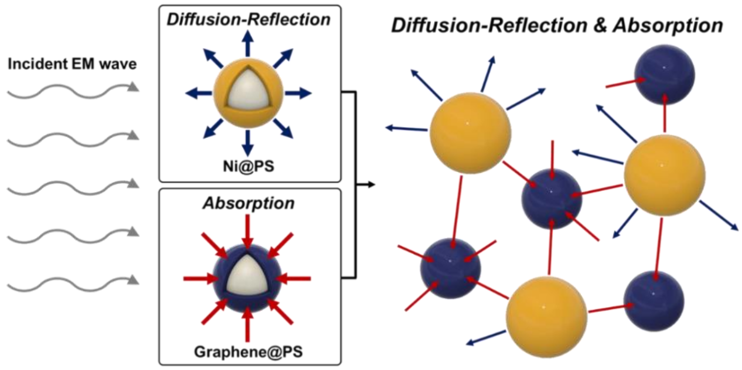
Fig. 1. Photographs of a multi-layer, flexible microstrip patch antenna composed of liquid metal encased in elastomer.

Professor Kim published 2 Journals (IET Science, Measurement & Tech, and IEEE Access) and 2 conference presentations (Korean Institute of Electromagnetic. Eng. Sci.)

Program Officer: Dr. Tony Kim

Project: Aperture Control in Polymer-based Composites with Hybrid Core-Shell Spheres for Frequency-Selective Electromagnetic Interference Shielding

Professor Jae-Do Nam, School of Chemical Engineering, Department of Polymer Science and Engineering, SKKU, Seoul, Korea is to focus on the fundamental research of two types of skin-core beads (“conductor@beads” and “absorber@beads”) and their high-performance composites for the development of a novel EMI shielding material system. The spherical beads could be quite unique in the task of EMI shielding because they redirect the waves repeatedly among the adjacent beads in the random direction until the EM wave sinks into the absorber. Also investigating the fundamental principle of the aperture effect of the composite system that could be varied by such parameters as packing density, bead size, and ratio of conductor@beads and absorber@beads. A holistic approach is taken performing both analytical modeling and experimental measurement for the identification of property-processing-structure relationship of this novel composite system that is applicable in various EMI shieling issues.

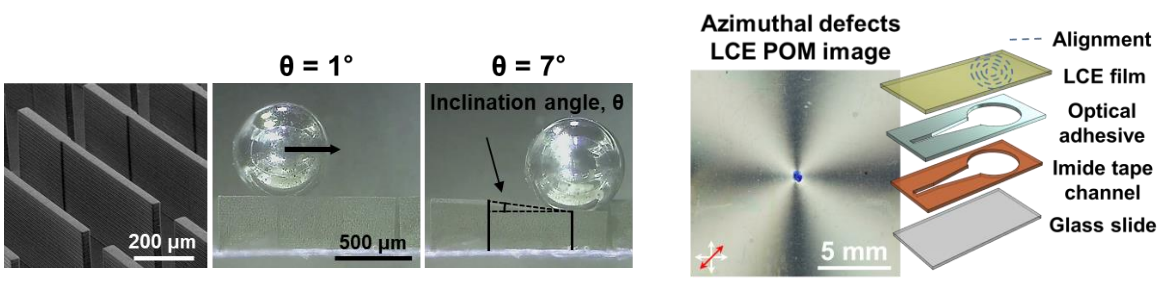


Schematic illustration of two different types of skin-core beads: diffuse reflection by "conductor@bead" and absorption by "absorber@bead." When these two beads are mixed in a composite structure, the redirected EM waves are absorbed and ultimately eliminated by the EM sink of absorber@beads.

Program Officer: Dr. Tony Kim

Responsive Substrates toward Mobilization of Liquid Metal RF Devices

Prof. Jeong Jae Wie from the Department of Polymer Science and Engineering, Inha University, South Korea is to investigate the feasibility of transporting liquid metal for radio frequency (RF) devices by two different systems, (1) Magnetically responsive polymeric microarrays, and (2) Microfluidic channels consisted with liquid crystalline elastomer (LCE) micro-valve. For magnetic system, programmed bending of micropillar arrays can be expected to control liquid metal flow. By pre-programming the molecular alignment of LCE, thermo- or photo- mechanical deformation of LCE will pressurize the liquid metal to fill in microfluidic channel. Magnetic microwall consisted with two discrete width have heterogeneous bending stiffness, resulting in height gradient along the microwall by magnetic bending. This gradient is utilized for gravitational force-induced liquid metal transportation. Adopting azimuthal aligned LCE for effective pressure to liquid metal via heat or light, resulting in microchannel filling.



The benefit is to have multi-layer flexible configuration antenna compose of liquid metal. To explore a dual-faceted approach toward tunable RF devices. Newly conceptualized contactless manipulation of shape-reconfigurable device for application in directional transfer of electric signals and switchable liquid metal antennas. This project is co-funded with AFRL/RX.
Program Officer: Dr. Tony Kim

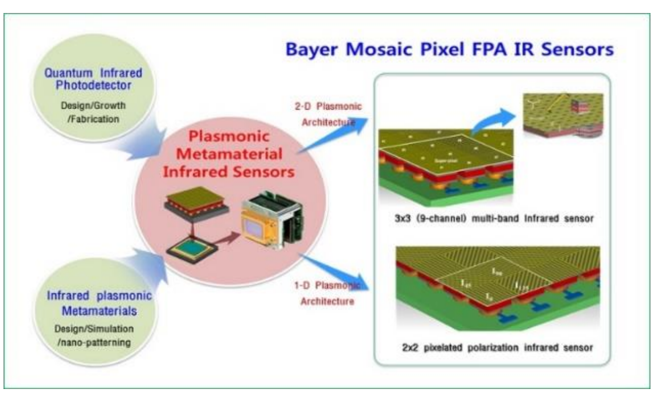
Project: Exploring Deep Learning-based robot perception techniques for navigating outdoor terrains

Professor. Han-seok Ko from the School of Electrical Engineering, Director of the Machine Learning & Big Data Institute, Korea University, Seoul, Korea is to investigate and collect label vision based sensor data from numerous viewpoints in an outdoor and unstructured environment. Using this to survey and select among modelling and simulation engines the most appropriate for the synthetic imagery data generated by a coupled GAN based method. This addresses the data scarcity problem in scene perception for Army ground robot systems tasked with traversing an unstructured environment (battleground, woodlands, urban aftermath, etc).

The benefit having this database collected will represent a baseline for many training and testing efforts in the future that need to overcome outdoor scene perception problems. Potential public uses are self-driving cars, autonomous delivery bots, and perception and navigation issues encountered after a natural or manmade disaster. This project is co-funded with ITC IPAC, DEVCOM/ARL, AFOSR, & AOARD and will be transition to ARL. Program Officer: Dr. Tony Kim

Metamaterial based pixel-level infrared imager for adaptive sensing

Dr. Sang-Un Lee from the Korean Research Institute Standard Science (KRISS), South Korea is to examine how metamaterial based couplers can be designed and implemented to improve compressive spectral, spatial and polarization sensing by considering the target feature set, the compressive sensing algorithm, and the modified sensor performance in the enhancement detector design. Impact to AF: Developing Infrared detector with multi-color and polarimetric performance, which is required for the 4th generation IR detector. Obtain the fundamental technology of ultra-light and low-power infrared imaging system by applying a pixelated sensor. This project was co-sponsor by AFRL/RX



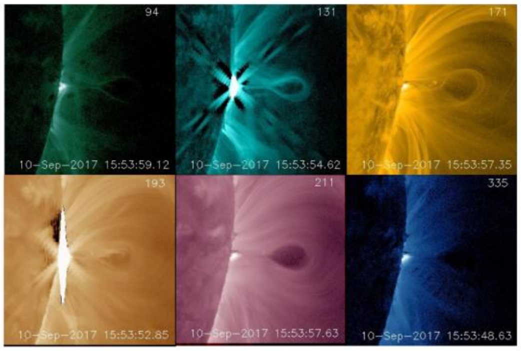
(1) Theory, E&M simulation & sensing algorithm
(2) MBE growth of infrared photodetectors
- InAs quantum dots-in-a-well
- Multi-quantum well (GaAs/AlGaAs)
- Type-II strain layer superlattice (InAs/GaSb)

(3) Focal plane array (FPA) device fabrication
(4) Device performance characterization
- Responsivity (*R*) & Detectivity (*D**)
- Noise equivalent temperature difference (*NEDT*)

Program Officer: Dr. Tony Kim

Ion composition properties in interplanetary coronal mass ejection (ICME) and post-CME current sheet (CS)

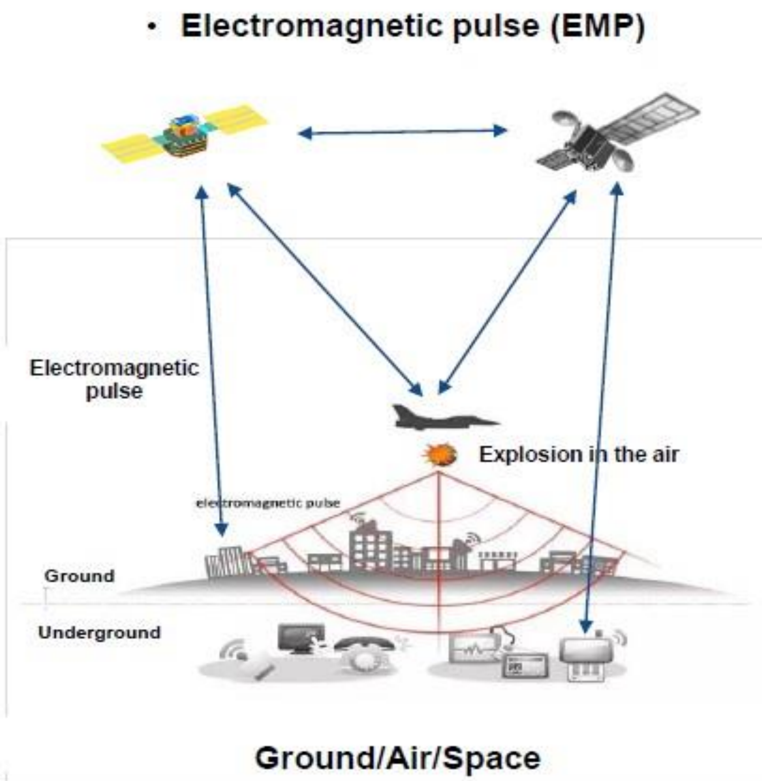
Prof. Jin-Yi Lee of Kyung-Hee University of South Korea is to investigate the nonequilibrium properties of a current sheet observed 2017 September 10 using a time-dependent ionization equation with various Kappa distributions and investigate the heating inside interplanetary coronal mass ejections (ICMEs) using variations of ion composition with Kappa electron velocity distributions. Coronal mass ejections (CMEs) are among the most energetic solar events. Solar energetic particles (SEPs) are accelerated at a CME shock. The SEPs, when reaching Earth, can cause severe space weather effects on such as satellites, navigation, communication, and Humans in space.



Flux rope eruption on 2017 September 10

Program Officer: Dr. Tony Kim

Frequency-Selective Electromagnetic Interference (EMI) Shielding Materials against Space threats & Space Environment. Professor Nam from the SKKU University in South Korea is to conduct Basic research in support of Space Situational Awareness (SSA) Sensors, Navigation, and Communication for space system protection using the EMI shielding. The space environment is hostile and hazardous such as electronics upset, Martials age, and Radio waves degradation. The space threats are real and growing and threat must be detected, and understood, and address. In order to perform the mission without any interference, corruptions, attack from the adversaries. We needs protect our space systems from both transmitted and received signals. EMI shielding material is one of the techniques that is easy, fast, effective, and low-priced to apply to the space systems. These EM pollutions and threats motivate a fundamental research of developing a smart EMI shielding material that has a capability of frequency-selective shielding of EM waves, i.e., desirably allowing us to choose specific frequency bands to pass or block. We believe that the utilization of this smart EMI shielding material is easy, fast, effective, and cheap to apply to the space systems. Potential benefits to AFOSR & USSF: Space system (Micro & Cube satellites) will be protected against adversaries on attacks. Current system signals will be less vulnerable against the threats and safer to transmit and received for the sensors, navigations and communication systems.



Program Officer: Dr. Tony Kim

David Ahn at the University of Seoul was awarded a new start grant in 2021. Every quantum algorithm is represented by set of quantum circuits. Optimization schemes for quantum algorithms and quantum computation is important especially when quantum computation is performed with limited qubit resources in NISQ-based machines. A major obstacle to this goal of optimization is the large number of elemental quantum gates that are required to build even small quantum circuits. Recently, Dr. Ahn proposed and demonstrated a general technique called quantum Karnaugh map (QKM) that significantly reduces the number of elemental gates necessary to build quantum circuits. His team demonstrated QKM could reduce the number of gates by 60% and 46% for the four- and five-qubit Toffoli gates, two key quantum circuits, respectively, as compared with the simplest known decomposition. Reduced circuit complexity often goes hand-in-hand with higher efficiency and bandwidth. By performing quantum circuit studies on an IBM-Q machine, another research group showed that a single CNOT operation can be reliably performed in a NISQ environment. Dr. Ahn and his team intend to realize QKM in a NISQ-based machine. Realizing quantum circuit optimization protocols in NISQ machines would provide leapfrogging ground for the optimization of quantum circuits & algorithms.

MALAYSIA

Mechanism of Warp Density and delamination on ballistic impact properties of laminated hybrid Bamboo/E-GLASS/ EPOXY Natural GREEN Composites.

Professor Aidy Ali from the National Defense University of Malaysia (UPNM) proposed the study to identify the fundamental mechanisms of warp weft density on the performance of bamboo composites towards mechanical delamination, mechanical fatigue and fracture and the effect of aging of natural composites towards environmental attack. Recent study and development of bamboo composites show the bamboo have superior strength when it is in laminated forms. In Year 2018, Aidy et al successfully developed and test a hybrid bamboo/E Glass/ UP hybrid composites. The developed composites were tested and reach the level Ill of National Institute of Justice (NU) standards. The fracture toughness found were similar with steel alloy. This hybrid bamboo is planned to be construction materials for high load transfer and antiballistic engineering components that promotes green technology as well as functioning for defenses. The applications of these new composites could be a key to the new construction of light well high structural integrity of ship hull for the naval applications. This research requires strong fundamental understanding on the mechanisms of bamboo composites strength from its waft weft density, laminated arrangement, processing parameters and treatment in order to move forward and realize them into practice. Unsaturated Polyester (UP), Woven Bamboo fiber (WB) and Woven E-Glass Fiber (WEG) are the materials used for this study. The bamboo was Gigantochloa Scortechinii (Bu/uh Semon tan) which was collected from Kampung Bukit La rang in Malacca, Malaysia. Program Officer: Dr. Tony Kim

Shock Wave -Boundary Layer Interaction Control in Mach 5 Hypersonic Flow using Combined Active Flow Control.

Professor Mohd Rashdan from the National Defense University of Malaysia (UPNM) proposed to investigate, optimized designs, and configurations of the combined active flow control mechanism, which will contribute to the design of future high-speed air breathing propulsion system and re-entry vehicles that delivers better performance. Understanding the SBLI phenomenon and the control methods will also reduce the risk of accidents associated with both space and high-speed air-breathing vehicles. From the previous investigations conducted on both passive and active techniques, the boundary layer separation region was not able to be eliminated entirely. The flow control devices only managed to decrease the size of the separation region. Therefore, the aim of this study is to combine different active flow control mechanisms such as plasma discharge, jet and suction at hypersonic Mach 5 flow to overcome this problem effectively and reduce the size of separation region significantly. This study will also propose the optimized configurations involving all three techniques and this will be achieved by carrying out experimental studies using the hypersonic wind tunnel at the University of Manchester facilities.

In the initial stage of this project, the fabrications of the all the models that will be tested will be done in Malaysia, using the CNC facilities at UPNM. This involves a flat plate with stands and various models of active flow control mechanisms; plasma discharge, jet and suction. The models will then be tested in the hypersonic wind tunnel facilities at the University of Manchester UK. The experiments will involve the use of state-of-the-art flow diagnostics tools such as Pressure Sensitive Paints (PSP), Particle Image Velocimetry (PIV), high-speed colored schlieren and surface flow visualization. From the experiments, the flow physics of the combined active flow control devices and the improvements introduced will be visualized from the discrete and field surface pressure measurements, flow velocity vectors and shock wave colored schlieren images. The geometries and positions of the combined active flow control mechanism will be optimized in this investigation, to obtain the most significant reduction in the size of the separation affected area due to SWTBLI. Program Officer: Dr. Tony Kim

Ascertaining the importance of biomarker and imaging modality in identifying the risk of Decompression Sickness (DCS) in high altitude.

Professor Shazreen Shaharuddin from the National Defense University of Malaysia (UPNM) proposed to investigate the potential of fluorescent sensors of hypoxia in detecting low Oxygen tension that could lead to hypoxia due long space flight at high altitude. The exploitation of these new technology detection would promise a novel potential role in detect and prevent the risk of developing hypoxia which can cause poor prognosis in the future of the air crews. There are three main objectives of this investigation related to the potential of fluorescent sensors of hypoxia as a diagnostic tool in detecting hypoxia at high altitude:

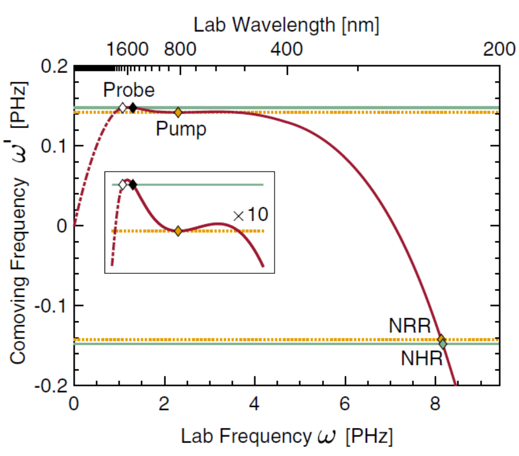
- To determine the specificity and validating of the fluorescent sensors of hypoxia in detecting physiological changes of biomarker of HIF-1α protein at high altitude.
- To determine the effectiveness of the fluorescent sensors of hypoxia in detect the onset of cognitive impairment due to lack of oxygen supply to brain by using the cognitive assessment on an air crews after 8 hours of flight.
- To develop the threshold values using the fluorescent sensors of hypoxia in detecting the risk of hypoxia.

Program Officer: Dr. Tony Kim

MEXICO

Optical Analogs of Hawking Radiation in the Quantum Regime

The objective is to develop an optics-based experimental platform for the observation of analog Hawking radiation (HR) seeded by single photons. Prior optical HR analog experiments have relied on a stimulated approach, in which laser radiation seeds the HR emission instead of the vacuum fluctuations as would be the case for spontaneous HR. We have identified an interesting intermediate regime in which HR is seeded by single photons obtained from photon pairs produced by the spontaneous four-wave mixing process in a fiber, thus retaining the quantum character of the Hawking effect. We aim to detect both photons generated in this single-photon-seeded HR platform and to study their quantum entanglement properties. We will additionally use our experience gained in order to shed light on the possibility of generating spontaneous, i.e. unseeded, analog HR. Our theoretical studies indicate that the measurement of the spontaneous HR effect in optics, i.e. directly from quantum vacuum fluctuations, is still extremely challenging due to the expected low generation rate. Nevertheless, we have found an intermediate regime that would allow us to test the quantum properties of HR: an analog stimulated by a single photon. Our planned experiments envisage a first phase in which we detect the HR single photons at 1600nm, in addition to the quantum entanglement properties with the SFWM photon at 481nm, inherited from the quantum entanglement properties of the original SFWM photon pair. The detection of the UV HR photon at 240nm is challenging since single photon detection in such a spectral region is less developed. Thus, as a second phase we will design another configuration based on a different fiber material, through numerical modelling, to yield the UV HR photon at a higher wavelength, which may facilitate single photon detection.



Doppler curve. Plot of ω' given by Eq. (2) for n(ω) and u of our fiber (solid curve: n determined from measurements, dashed-dotted: n extrapolated). The pump pulse sits at a local minimum and the horizon at a local maximum; ω' is conserved during pump-probe interaction (horizontal lines). The probe light (black and white diamonds) is incident with frequencies lower or higher than the horizon, experiencing the analogue of a black or a white hole. Both incident and outgoing Hawking partner have –ω' of the probe (lower line) intersecting the Doppler curve where we expect negative Hawking radiation. The pump itself creates negative resonant radiation (NRR) at the intersection of its –ω' (lower dotted line) with the Doppler curve. (Courtesy of Drori et al. 2019).

Netherlands

Low-level estimation and control with a fully spiking neural network autopilot for autonomous drone flight

Prof Guido De Croon, University of Technology Delft, Netherlands

The onboard execution of deep artificial networks required for edge computing is limited for small and lightweight drones due to size, weight and power requirements. Spiking neural networks (SNNs) form a novel generation of neural networks highly promising to address this issue. Neurons in SNNs fire sparsely, asynchronously, and only spend energy when firing which results in fast runtimes and orders of magnitude energy reduction. Technology companies have started to design hardware specifically for spiking neural nets but due to their nature, the creation and training of SNN cannot be done with traditional backpropagation methods. Thus far, SNN have only been applied to relatively simple tasks. Professor Guido De Croon's research is to create a fully spiking neural network autopilot for autonomous drone flight.

During the past year, the team took the first steps to achieve this goal by focusing on altitude control and attitude estimation for quadrotors with spiking neural networks. Professor De Croon and his team successfully implemented the equations governing a proportional–integral–derivative (PID) controller in spiking neurons on Intel Kapoho Bay neuromorphic hardware and used it to perform altitude control of a quadrotor by controlling Thrust (T). A comparison between the step-response of a standard PID and the developed neuromorphic PID with a resolution of 151 neurons is shown in Figure 1.

This implementation, and the knowledge obtained by this initial work can be further expanded to control roll (θ), pitch (Φ), and yaw (ψ) currently controlled by a host machine via wireless protocol as shown in the current hardware architecture diagram, Figure 2. Initial work creating a recurrent neural network for these controls has been promising when compared to a common Madgwick-filter.

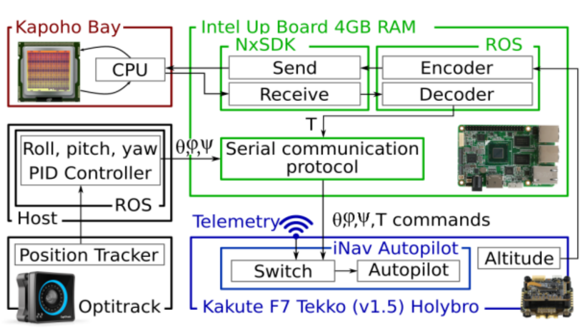


Figure 2: Overview of Quadrotor Hardware Architecture

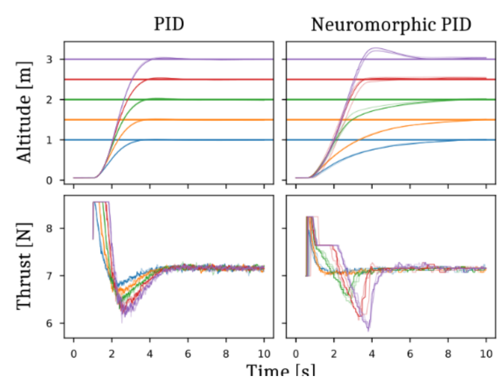


Figure 3 Step-response comparison between a regular PID and developed neuromorphic PID

The research in the upcoming year will generalize the developed methods to work for a variety of quadrotor types and leads the way towards the development of small fully autonomous drones capable of real world missions.

14 Sept 2021 – Professor Lieven Vandersypen has been awarded the Spinoza Prize – also known as the Dutch Nobel Prize - from the Dutch Research Council (NWO). He will receive 2.5

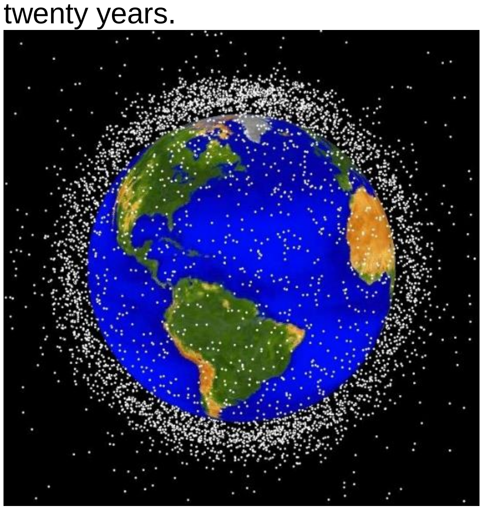
million Euros for his contributions to condensed matter physics especially regarding quantum control of electrons. Vandersypen was part of team that factored 15 (5 x 3) using nuclear spins to implement Shor's quantum factoring algorithm. From 2010-13 he was sponsored by AFOSR's European Office of Aerospace Research and Development for work on Quantum Simulation in Quantum Dot Arrays (dtic.mil). That work forms part of a progression that has led to his hope to enable quantum computing. For more on that and his future outlook see this excellent interview Delft Spinoza Prize winner has remarkable plans for his funds (tudelft.nl). POC Dr. Scott Dudley

Photo from https://www.delta.tudelft.nl/sites/default/files/styles/1200x/public/images/lieven-vandersypen_NMC3007-scaled.jpg?itok=kU1bLnyR

NEW ZEALAND

Successive convex optimization to address challenges in space situational awareness: Professor Roberto Armellin from the Auckland Space Institute, University of Auckland is currently performing basic research addresses SSA concerns: The number of cataloged space objects (SO) is expected to drastically increase. The increase in the number of active spacecraft is mainly due to miniaturization (e.g., CubeSats) and the launch of mega-constellations. In parallel, the number of tracked space debris will significantly grow due to the improvement in tracking systems (e.g., the space fence system).
His research will be in two part.

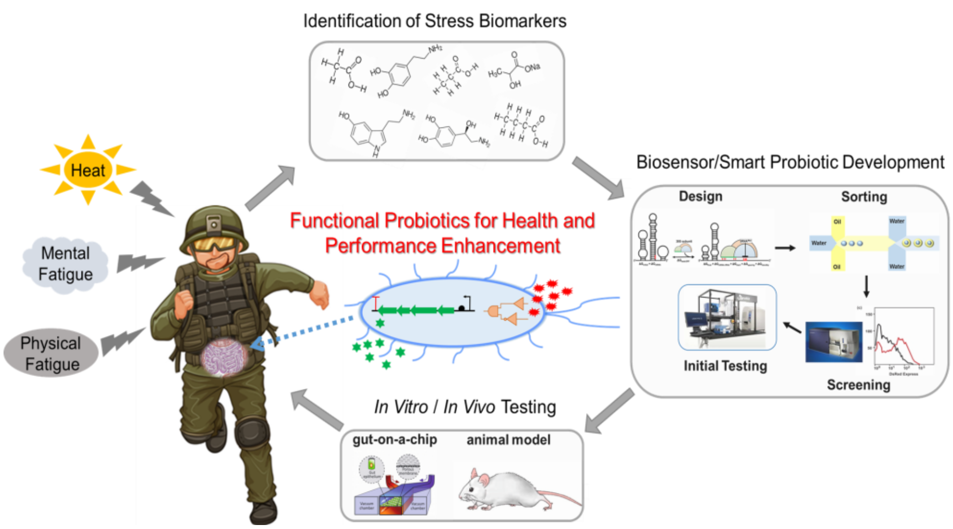
1. Maneuvers estimation for track correlations. Low data density, which is the norm in Space Situational Awareness (SSA), increases ambiguity in data association and ignorance in hypothesis resolution.
2. Multiple-conjunction collision avoidance maneuver (CAM) design. Conjunction analysis and collision avoidance are currently performed by agencies and operators on-ground using several tools and processes that were developed over the last twenty years.




Program Officer: Dr. Tony Kim

SINGAPORE

Researchers at AFRL's Human Performance Wing, Northwestern University and National University of Singapore and the international program officer at AFOSR/AOARD held a kickoff meeting for basic research collaboration to identify, improve, and test novel protein based sensors for human performance monitoring and future intervention predictive models. As the first Country Initiative with Singapore, AFOSR/AFRL is funding both AFRL/ Human Performance Wing and Northwestern University researchers, and is leveraging Singapore's Ministry of Defence to fund researchers from the National University of Singapore. The research plan has each research institution tasked with a specific goal based on their respective expertise: AFRL researchers are tasked with biomarker identification and improvement; Northwestern researchers will focus on optimizing and fine tuning biosensors application and testing, and National University of Singapore researchers will use their expertise to integrate the improved biomarkers and evaluate performance with animal studies. The end goal of the collaboration is to create novel sensors and integrate into future fieldable sensing platforms for our airman and guardians and provide a solid basic research framework for future applied government-to-government research activities.



[RXCM Multiple WOS Project Developments]

SLOVENIA

Retinal Mechanisms of Detection of Polarization and Color

Over the past several decades, we have witnessed an explosion of autonomous vehicles for defense and civil applications. These platforms have been used for wide variety of applications such as targeting, navigation, search and rescue, monitoring and surveillance, terrain mapping etc. These devices are usually large and heavy and have intense energy needs; One way to better understand how these challenges could be addressed is to turn to biology. Flying insects are incredible navigators, display impressive collision avoidance skills, and can seek and capture prey effectively. Studying the behaviors and physiology of these insects allows for the development of simple, lean and efficient algorithms for visual guidance and targeting. Professor Gregor Belusic's research in the University of Ljubljana focuses on the retinal mechanisms of detection of polarization and color in diurnal butterflies. His team has established, for the first time, a clear association between the composition of the butterfly eye shine, physiological properties of the cells in the compound eye and the matrix of ommatidia. This leads to proper understanding of the butterfly compound eyes as a blueprint for the optimal miniaturized imaging sensor.

Program Officer: Dr. Nandini Iyer

SRI LANKA

AFOSR IOA Grant forges new research relationship with Sri Lanka

AFOSR IOA has a new partner country! For the first time, an AFRL/AFOSR grant has been awarded in Sri Lanka, beginning in FY21. With AFOSR support, Professor RMG Rajapakse at the University of Peradeniya will lead a computational and experimental study of control and tunability of IR-active nanocrystal-core/conducting-polymer-shell nanocomposite materials.

The research team will conduct computational simulations varying polymer architecture, electron donating and accepting groups, and ceramic core dopant parameters to understand composition-structure-property relationships, thereby guiding experimental studies. A range of chemical syntheses and characterizations are planned, first for the individual conducting-polymer-shell and nanocrystal-core components, then for the combined core-shell nanocomposites. The team will investigate an electropolymerization technique that avoids the use of hazardous transition metal catalysts. Also, the polymeric shell design provides compatibility advantages with synthetic and biologic systems. Tailorable electro- and photo-active materials have the potential for broad applications such as sensing and power management for awareness and mobility in the terrestrial and space environments. New knowledge of basic structure-property relationships could enable tailorable interconversion of energy across the UV-Vis-IR spectrum for technologies where electromagnetic energy absorbance, attenuation, scattering, or conversion are desired.

In addition to the technical expertise that Prof. Rajapakse brings to bear, he has already proven to be an important conduit for establishing new relationships throughout the Sri Lankan research community that will help to build a lasting and meaningful partnership between AFOSR IOA and Sri Lanka. He has facilitated introductions to IOA of nearly a dozen researchers at Peradeniya and other Sri Lankan institutions including the University of Colombo and the University of

Jaffna. As FY21 concluded, following from these introductions, an all-female team of researchers were preparing a basic research proposal for submission to IOA on new chemical pathways for difficult separations of desirable metals found in natural mineral sands native to Sri Lanka.

Prof. Rajapakse has a remarkable professional network offering access to people and facilities around and beyond Sri Lanka. In addition to his collaborations at national-level research institutes in Sri Lanka, several of which are led by his former students, Rajapakse has strong international ties including those with researchers at the National Renewable Energy Laboratory in Colorado, Temple University, the University of Mississippi, Western Norway University, and Newcastle University, all of which will contribute in some way to the present IOA project on core-shell materials.

While Prof. Rajapakse will focus his team's efforts on basic research under the new AFOSR IOA grant, he also keeps an eye toward new technology applications that can leverage basic science with Sri Lanka's natural resources for the greater socio-economic benefit of Sri Lanka. For example, in the months leading up to the IOA grant, Rajapakse led a team that developed, patented, and commercialized a new product for protection against COVID-19. They produced a 3-ply face mask with a superhydrophobic outer layer, particle retention and antiviral middle layer, and soft comfort inner layer, all made of nano-engineered cotton. Program Officer: Dr. Todd Rushing, IOA

SWITZERLAND

Professor Maksym Kovalenko of ETH Zurich, Kovalenko Lab - Functional Inorganic Materials | ETH Zurich, funded by AFOSR's European Office of Aerospace Research and Development (EOARD) in conjunction with the Office of Naval Research's Global (ONRG) has been awarded the Hebrew University of Jerusalem's 2021 Dan Maydan Prize for Nanoscience Research for his work on the chemistry of nanocrystals. With over 32,000 citations per Maksym V. Kovalenko - Google Scholar, Kovalenko makes most highly cited lists and the group's seminal 2015 Nanocrystals of Cesium Lead Halide Perovskites (CsPbX3, X = Cl, Br, and I): Novel Optoelectronic Materials Showing Bright Emission with Wide Color Gamut | Nano Letters (acs.org) now has over 4,000 citations. The AFOSR grant targets photon emission from the perovskite colloidal dots and their superlattices. Kovalenko is also the recipient of the Rössler Prize 2019: Maksym Kovalenko awarded by ETH Zurich. For an excellent one hour introductory lecture see Maksym Kovalenko (ETH Zurich, Empa) "Highly Luminescent Perovskite Nanocrystals". POC Dr. Scott Dudley

The Light Emitting Properties of Perovskite Quantum Dots

AFOSR European Office of Aerospace Research and Development (EOARD) in conjunction with the Office of Naval Research's Global (ONRG) office has started a grant with Maksym Kovalenko, Maryna Bodnarchuk, Gabriele Rainò, at ETH Zurich and Empa to study the light emitting properties of perovskite quantum dots. The group's 2015 Nano Letters paper has been cited over 4,000 times to present. In the grant with Maksym Kovalenko that has some possibilities for single or N-photon sources. If you have the time I've attached a 2015 article which is sort of the breakout year for these perovskites, probably a skim as it's really more chemistry. The 3-minute video below is pretty, and then at the end of the long video he mentions the quantum photon sources, which is what I'm interested in pursuing. It's one of my most exciting possibilities and I'm working with my Navy counterpart Andrey Kanaev, who's also a Rochester grad, small world!

Here's the 3-minute 2019 Rossler Prize video which is pretty to watch, https://www.youtube.com/watch?v=8_WeqHSCCtU

Here's the 1-hour intro video from Maksym, https://www.youtube.com/watch?v=kxQh4X13V2Y, which is a great intro and only a month old, Sept 2020, quantum sources just mentioned at the very end.

Exciting stuff and it's making me learn a bunch of big word chemistry! If you have time for another phone chat next week, I'd like that a lot too. I really want to ask what sources and detectors you all use or would like to have, as I think that's a major funding area for me over here. Cheers, Scott

TAIWAN

Professor Gaetano Currao from National Cheng-Kung University (NCKU) in Tainan, Taiwan will study how the skin panel of a hypersonic vehicle behaves at transonic speeds, where abrupt forces may be applied due to newly formed shocks impinging on the surface. This will complement work being done at UNSW in Canberra on fluid-structure interaction within this portfolio, using transonic wind tunnel facilities at NCKU. It is possible that in some scenarios, the off-design transonic conditions present a worst-case for a hypersonic glide vehicle. This project will seek to improve the fidelity of physical understanding and numerical models in this regime.

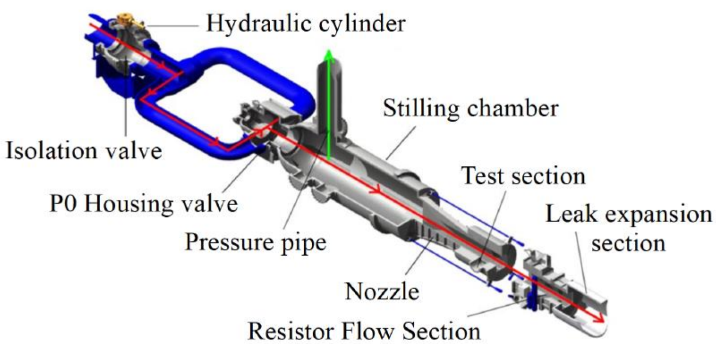


Figure 4. The ASTRC/NCKU Transonic Wind Tunnel

Robustness Verification for Systems under Denial-of-Service Attacks
PI: Associate Professor Chung-Wei Lin, National Taiwan University, Taiwan
Project Duration: Jul 2019 – Jul 2021 (Completed)
This two-year project investigated systems under denial-of-service (DoS) attacks and modelled the attacks under weakly-hard fault models. A weakly-hard fault model constrains a scenario to where the number of malicious events (m) is equal or less than any discrete number of consecutive events (k). The research yielded approaches where it is possible to verify properties for all possible values of (m,k) when examining a system less than equal to a given constant (K) in an exact and efficient manner. Research output during this project includes papers to the International Conference on Runtime Verification (RV) and the International Conference on Computer-Aided Verification (CAV). The work also included US collaborations with Prof. Eunsuk Kang (Carnegie Mellon University) and Prof. Qi Zhu and Dr. Chao Huang (Northwestern University). This project was co-funded with support from ONRG.
Program Officer: Lt Col Alan Lin, USSF

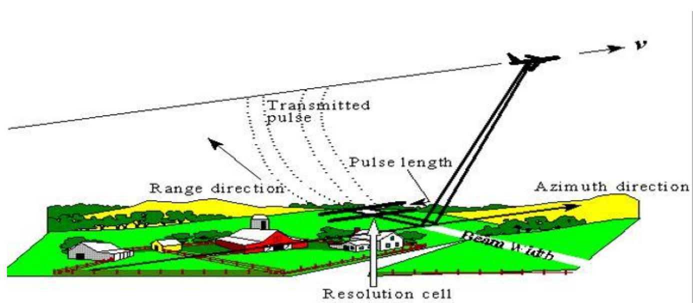
Study of Privacy Preservation Techniques for Deep Learning
PI: Assistant Professor Pei-Yuan Wu, National Taiwan University
Project duration: Aug 2020 – Aug 2022 (In progress)
The first year of the project investigated methods to achieve compressive privacy in video. Experiments on the proposed Privacy-Preserving Class Overlap Network (PPCON) architecture, incorporating both Wasserstein Generative Adversarial Networks (WGAN) and the idea of class overlapping, achieved better utility-privacy trade-off in race-preserving gender classification and

identity-preserving action recognition problems, while simultaneously reducing the number of parameters compared to other state-of-the-art methods. This project was co-funded with support from ONRG and supported two MS students to graduation. The project also received complementary funding from a general research grant domestically sponsored by Taiwan's Ministry of Science and Technology (MOST). Program Officer: Lt Col Alan Lin, USSF

Collaborative Decision Making: Evaluations of Methodologies and Cognitive Design
PI: Distinguished Professor Huei-Tse Hou, National Taiwan University of Science and Tech
Project duration: Sep 2020 – Sep 2022 (In progress)
The first year of this study examined engagement and anxiety in a decision-making training activity. Motivation and acceptance was found correlated with engagement. Anxiety did not correlate to other dimensions when performed in a group, but adversely affected flow and game acceptance in individual settings. This grant supports the PI, a researcher, and two part-time assistants and produced in a paper in the 13th Asian Conference on Education (ACE2021). Program Officer: Lt Col Alan Lin, USSF

Full Wave Simulations of Bistatic Radar Clutter of Rough Ground Surfaces, Vegetation, and Trees between 1 GHz and 10 GHz

Professor. Jeff Kiang from the National Taiwan University, Taiwan is to investigate the application of bistatic radar configuration combined with polarimetry and interferometry techniques to enhance radar detection in complex environments. Frequency dependent backscattering using the physical models and development of algorithm with extensive ground measurements data for validation and verification.

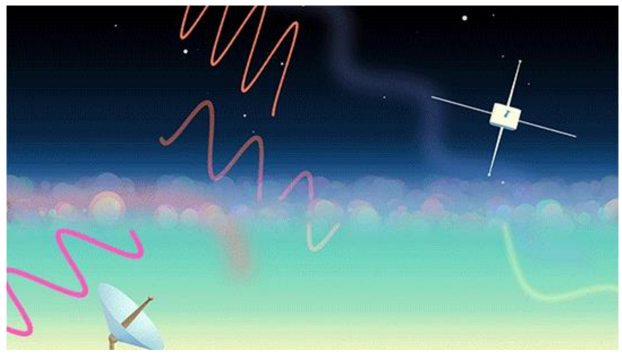


Bistatic clutter is part of the ground environment that affects the performance of a bistatic radar system. In continuous wave (CW), moving target indication, and pulse doppler radars, bistatic *clutter residue* (clutter return after signal processing) competes as interference with the target signal. In synthetic aperture radar, bistatic clutter is a critical part of the target scene.

Program Officer: Dr. Tony Kim

Study of Ionospheric Effects on Space Communication and Navigation

Professor Lung-Chih Tsai from the National Central University of Taiwan is to investigate the Radiowave scintillation caused by ionospheric density irregularities which will degrade the space communication/navigation quality. The goal of the proposed project is to study the irregularity characteristics and global occurrence distributions (solar maximum vs. solar minimum) so as to assess the impacts on communication, navigation and positioning system. Project will perform research by using Hilbert-Huang Transform (HHT) to study the ionospheric irregularity structure and the related radiowave scintillation to understand the irregularity structure/scintillation characteristics. To construct a global/seasonal scintillation map using the recently launched FS-7/COSMIC-II GPS RO signals obtained during the ascending phase of solar cycle of 25. _To develop the Taiwan Ionosphere Model 2 (TWIM 2) using FS-7/COSMIC-II GPS RO data.



Qubit Efficient Encoding Scheme

Professor Hsi-Sheng Goan from Taiwan National University in Taipei Taiwan reported on the first year's work on quantum control and quantum computing. The project is focused on two issues on quantum control and quantum computing to develop a qubit encoding scheme and to design AI algorithm under evolutional optimization. First, PI proposes a generalized qubit efficient encoding scheme (QEE) that allows fewer qubits than the conventional encoding method. The simulation experiments were effectively tested using real IBM Quantum machine. It can be shown that the QEE will be applicable to quantum simulations for larger molecular systems in NISQ machine in the future. Secondly, PI presents variational quantum reinforced learning under quantum computations. Two frameworks were considered using evolutionary optimization techniques. One is the amplitude encoding scheme and the other is the tensor network-variational quantum circuit (TN-VQC) architecture as shown in Fig.1.

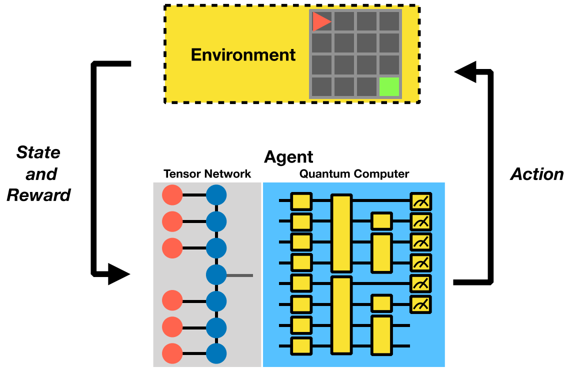


Fig. 1 A hybrid tensor network-variational quantum circuit (TN-VQC) architecture to handle inputs with dimensions exceeding the number of qubits for quantum reinforcement learning (QRL)

Professor Ming-Chiang Chung from National Chung-Hsing University in Tainan, Taiwan reported on the first year's project on determining of topological quantities in condensed matters through quantum information and deep learning. PI built a recipe to do the supervised/unsupervised learning for determining the topological phase transitions as illustrated in Fig. 2. One can also use this recipe while handling other type of correlations, *e.g.* spin-spin correlations as inputs. The work of the second year project include the determination of the dynamical topological phase transitions and the phase transitions of strongly correlated systems using these recipes.

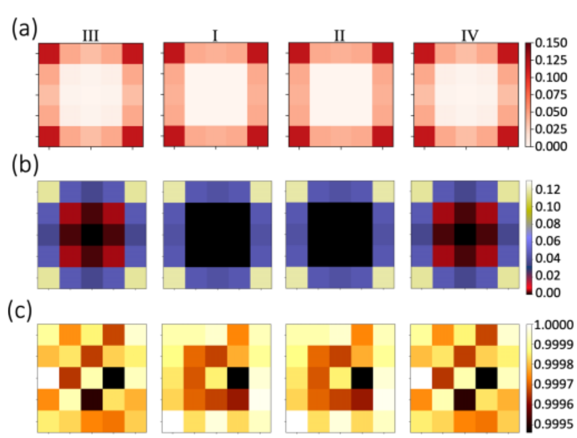


Fig.2 For a 2-D chiral p-wave superconductors

Program Officer: Dr. Fumio Kojima

Tying it back to the Lab

A key pillar of the AF 2030 strategy is: “The Air Force will expand and deepen access to scientific and technical talent through internal workforce enhancement and stronger partnerships across the national and international enterprise.” This is further emphasized in objective 3: “Air Force technological superiority has always relied on a national and international enterprise, including government laboratories and a synergistic network of universities, industry, and allies. As allies and adversaries become more technologically capable, these relationships will become even more important.” In the spirit of AF 2030 guidance, a new operating instruction (OI) is being developed to define and reaffirm the international initiative model.

Many XOARD international program managers are detailees from a technical directorate (TD). It’s hard to envision being any more tied to the lab than that! A pilot study has been conducted to include TD researchers as partners in AFOSR/IO’s international initiative programs with Taiwan, South Korea, and now Singapore. Moving forward, teams of 3 are envisioned to include a TD PI, international university PI, and a US university PI. See Singapore section for the first example of this.

TD participation in international initiative program from FY15 to present

Title	Location	Country	Principal Investigator
Graphene Infrared Transparent Electrode (GITE) and Thermal Enhancer for the Hybrid Energy Nanodevice	Air Force Research Lab National Dong Hwa Univ	US Taiwan	Mou, Shin Ma, Yuan-Ron
High-Conductivity and High-Mobility Doped AlGaN for Electronics and Optoelectronics Applications	AFRL/RXAP National Taiwan Univ	US Taiwan	Averett, Kent Yang Chih-Chung
Development of Biocompatible X-ray Scintillating Nanoparticles for Biomedical Applications	AFRL/RXAN Academia Sinica	US Taiwan	Boeckl, John Hwu Yeu-Kuang
Mechanically robust and photo-reconfigurable epoxy nanocomposite by dynamic covalent reaction	AFRL/RXCC Hanyang, Univ	US South Korea	Nepal, Dhriti Kang, Young Jong
Programming for graphene properties via defect design and characterization	AFRL/RX Hanyang Univ	US South Korea	Pachter, Ruth Park, Won Il
Exploring and Exploiting Transient Phase Diagrams in Electronic Materials	AFRL/RXAS National Taiwan Univ	US Taiwan	Glavin, Nicholas Hofmann, Mario
Layered Topological and Functional Materials: Single Crystal Synthesis, Characterizations, and Applications	AFRL/RXAP National Cheng Kung Univ	US Taiwan	Susner, Michael Lue, Chin-Shan

An example highlight of a FY21 new start with Dr. Nicholas Glavin from AFRL/RX and Prof. Mario Hofmann from National Taiwan University seeks to massively accelerate the design of sensor materials.

Program Officers at AFOSR/AOARD, researchers in AFRL/RX, AFRL/RH, and academic partners in the US and Taiwan are developing a strategy to significantly accelerate the design of chemical sensors built around 2D materials. While these materials have demonstrated unprecedented sensitivity in detecting chemical and biological threats relative to many commercial materials, they are many times limited to a handful of devices as fabrication can be challenging. AFRL pioneered a laser processing method to convert amorphous molybdenum disulfide (MoS2) to the subsequent crystalline phase, which rapidly generated over 5500 unique and distinct conditions on single chip. The generation of structural/property relationships from this massive series of parameters enabled the data-driven design of chemical sensors, where the device performance was shown to be strongly dependent upon thickness and grain orientation and less dependent upon expected parameters including defects, crystal size, strain, and doping.

United Kingdom

AFOSR sponsored researcher Professor Bob Coecke appointed Chief Scientist of Cambridge Quantum Computing –

Cambridge Quantum Computing, a leader in quantum software and algorithms, announced on 6 Jan 2021 the appointment of Oxford Professor of Quantum Foundations, Logic and Structures Bob Coecke as its chief scientist. Professor Coecke has been instrumental in the development of quantum programming with his group at Oxford growing to 50 members over the past 15 years, and with former members spawning groups elsewhere. Professor Coecke will be based at CQC's newly opened Oxford campus. In addition, Coecke is the co-author of the book *Picturing Quantum Processes* (2017) with fellow and current-AFOSR funded researcher Professor Aleks Kissinger, also at Oxford. The work on algorithm development is essential for being ready to take advantage of quantum computers when they arrive, and to take full advantage algorithms and hardware will need to be examined as coupled entities.

On a historical note, category theory, which Coecke and Kissinger are applying to quantum algorithms, was developed by Saunders Mac Lane (1909-2005), another AFOSR-funded researcher from early days. In *Picturing Quantum Processes* they reference several of Mac Lane's works from his 1963 paper "Natural Associativity and Commutativity" to his highly-cited book *Categories for the working mathematician* (1998). Mac Lane's book *Homology* (1963) includes in its preface the complement, "For many years the Air Force Office of Scientific Research supported my research projects on various subjects now summarized here; it is a pleasure to acknowledge their lively understanding of basic science."

Press release from Cambridge Quantum Computing: https://cambridgequantum.com/cambridge-quantum-computing-appoints-oxford-university-professor-bob-coecke-as-chief-scientist/

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Press release from Cambridge Quantum Computing: https://cambridgequantum.com/cambridge-quantum-computing-appoints-oxford-university-professor-bob-coecke-as-chief-scientist/

Quantum photonics startups in the news! This past week has seen exciting news stories regarding startup companies pursuing quantum computing with photons. Forbes reported on PsiQuantum’s announcement of its partnership with Global Foundries and recently PsiQuantum’s CEO Jeremy O’brien gave a talk at the APS March Meeting detailing progress and projected they are on track to deliver their Q1 computer by mid-decade, which will enable useful quantum computations. Also in quantum photonics, startup Xanadu is in the news with Bessemer Venture Partners leading a $100 million investment in the company founded by Christian Weedbrook. Former Xanadu member Kamil Bradler has moved to ORCA Computing’s team as its Head of Architecture. Orca is based in London where Ian Walmsley and Josh Nunn are two of its co-founders. For those following the money there are large bets and fine personnel aiming to have photons beat out ions and superconducting junctions as the physical system underlying the first useful quantum computer. All the above names are principal investigators or co-authors on former AFOSR basic research grants. POC Scott Dudley

20 May 2021 - Professor Sandra Chapman of the University of Warwick is a recipient of the 2021 Lloyd’s Science of Risk prize in the Climate Change category for work she co-authored on Temperature variability implies greater economic damages from climate change | Nature Communications. Professor Chapman’s grant with AFOSR is focussed on exploring other risks, specifically vulnerabilities associated with solar physics and its influences on the near Earth space and terrestrial environment. Her most recent contribution in that area just appeared Nature Communications as well on Network community structure of substorms using SuperMAG magnetometers | Nature Communications. For more on this prize see ‘Risk’ prize recognises research by University of Warwick physics Professor into economic damages of climate change and congratulations to Professor Chapman! POCs Drs. Scott Dudley and Nate Lockwood

Photo from: https://warwick.ac.uk/services/communications/medialibrary/images/june2017/d2790-77.jpg

Press release from Lloyd’s Lloyd’s announces 2021 Science of Risk prize winner (lloyds.com)

Nanomaterials possess some unique properties that make them very attractive in biosensing applications. Carbon nanotubes (CNT) and their single-walled counterparts (SWCNT) can serve as scaffolds to capture biomolecules and using several properties (optical, electrical, chemical etc.), can help with the transduction of signals associated with the recognition of analytes of metabolites. These characteristics, in conjunction with the ability to cross biological barriers such as cell membranes is of major interest for biosensing applications, especially as it pertains to the health, fitness and physical condition of airmen. Professor Matteo Palma (Queen Mary University of London) works very closely with scientists in the Airmen Systems Directorate to gather fundamental insight on the effect of biomolecular recognition on the properties of carbon nanotubes (CNTs)-based nanosensors, so as to development and advance the use of portable biosensors of Airman biosignatures. The team has assembled single-walled CNT (SWCNT)-aptamer hybrids as biosensors and demonstrated differences in the real-time electrical responses of the biosensing devices in two different configuration: i) tethering the aptamers to the CNTs in solution prior organization in devices (decreased conductance upon biomarker recognition), and ii) tethering the aptamer to the CNTs already organized in device configuration (increased conductance upon biomarker recognition). The finding is important because it suggests that local electrostatic property act at the key driving force, and that this in turn can provide and ability to tune the gating of electrical biosensors toward optimized detection

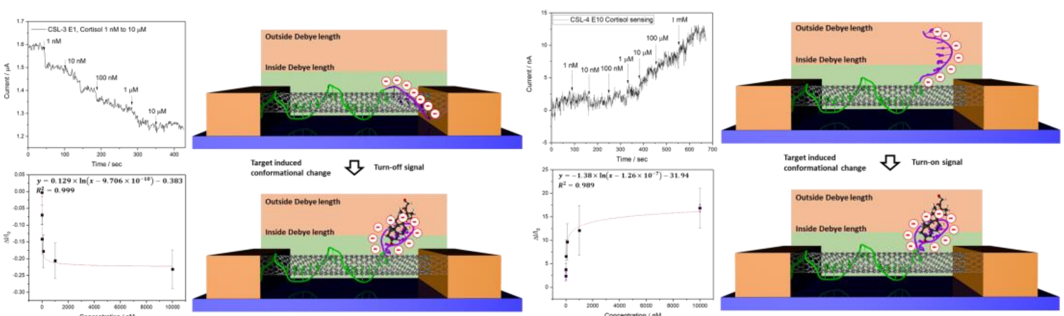


Figure 1. Orientation-dependent gating of conductance. Conductance across SWCNT functionalized with a) tethering the aptamers to the CNTs in solution prior organization in devices b) tethering aptamer to the CNT already organized in the device. The 0.1, 0.5, 2, and 10 pmol amounts are equivalent to the following molar concentrations: 10, 50, 200 and 1000 nM respectively.

Human-Machine Teaming (HMT) and AI forms an important part of the DoD modernization priorities and is envisioned to provide an advantage in future warfare. However, like with every successful team, the success or failure of the team depends on trust. Two grants in England supports foundational efforts in understanding and incorporating trust in intelligent machines and advance the DoD's vision of machines as trusted partners.

Professor Yeung's group aims to characterize and increase trust in human-machine teaming by leveraging insights from research on trust and influence in human social and group decision-making. To that end, the group is conducting two complementary streams of research to investigate (1) the causes and consequences of algorithm aversion, whereby human operators systematically down-weight advice from artificial systems after seeing them err; and (2) the features of algorithmic design that promote trust in advice from artificial systems. The grant is in its last year of funding and has largely focused on validating a survey tool called the Intelligent Systems Survey with a series of online experiments. Another survey tool for capturing individual differences in propensity to trust algorithms is also being developed under this effort. Using Machine Learning with bootstrapping, the investigators were able to extract a robust 3-factor survey that will be validated with further online studies. Moreover, the two surveys were important in that they were leveraged heavily by the group in their Bilateral Academic Research Initiative (BARI) effort that focuses on artificial intelligence and collaborative decision-making. Professor Cangelosi's project aims to design a computational cognitive developmental architecture for the design of ToM capabilities in agents, and its role in contextualized human-machine trust interactions investigating the effects of developmental, social and contextual factors in ToM and trust. Novel human machine interaction (HMI) experiments used the investment game protocol, as a trust interaction task, to manipulate different levels of ToM. Results show that the average investment (i.e. trust measure) in the high-level ToM condition is significantly higher than that in the low-level ToM condition. This demonstrates that participants are sensitive to the perception of the agent's ToM abilities. In parallel, a computational model of the two levels of ToM was developed using the latest deep learning methods applied to a (simulated) agent object manipulation task. Analyses on the agent's strategies show that the agent differentiates between lower-level "actional ToM (i.e. prediction of the action's goal) and higher-level "attitudinal ToM" (prediction on the intentions). The approach is now being extended to HMI in multi-agent scenarios where a group of humans are interacting with a variable number of agents, forming a heterogeneous team which is acting towards a common goal. This model will realize a cognitive architecture for dyadic interactions based on qualitative spatial relationships, with the purpose of extending it to handle the presence of multiple humans and agents (partially observable scenarios, data fusion, team organization).

In military operations, analysts often need to process texts from many different languages. Historically, these tasks were often undertaken by foreign language experts and were limited to languages of high operational importance. In such instances, access to machine translation is key to improving timeliness of critical information. Despite significant recent improvements, translations generated by existing neural approaches are still far from perfect. One of the reasons is the limited way in which they model the context of the texts to translate. They are based on textual examples of translation only, and disregard any additional information that may be associated with the text, such as images or metadata. This becomes more critical when translating content that is naturally multimodal, such as picture posts on social media, movie audio descriptions or subtitles. Professor Lucia Specia (Imperial College) uses multimodal machine translation, where, in addition to textual context, models leverage other modalities, such as images, videos or acoustic information. The motivation is that these modalities will provide richer context, helping ground the meaning of the text and, as a consequence, generate more adequate translations. Over the last year, Prof. Specia has implemented supervised attention mechanisms to map source or target words to image regions, addressing both attention at encoding time (i.e. learning alignments between source words and objects in the image) and at decoding time (i.e. learning alignments between target words and objects in the image), as well as improving the underlying multimodal neural machine translation architectures and fusion strategies to use such information and exploring more recent and better types of visual features. In doing so, she has leveraged information from multiple vision-and-language tasks and datasets to improve multilingual grounding. Experiments conducted on the Multi30K dataset for three language pairs: English–German, English–French and English–Czech showed that the multimodal referential grounding models outperform existing MMT models according to automatic and human evaluation metrics. Future work will explore ways to further improve image segmentation and object–word alignment to make the referential grounding approach applicable to any dataset.

Understanding the Optical Light Curves of LEO Spacecraft: the Application of Machine Learning Techniques

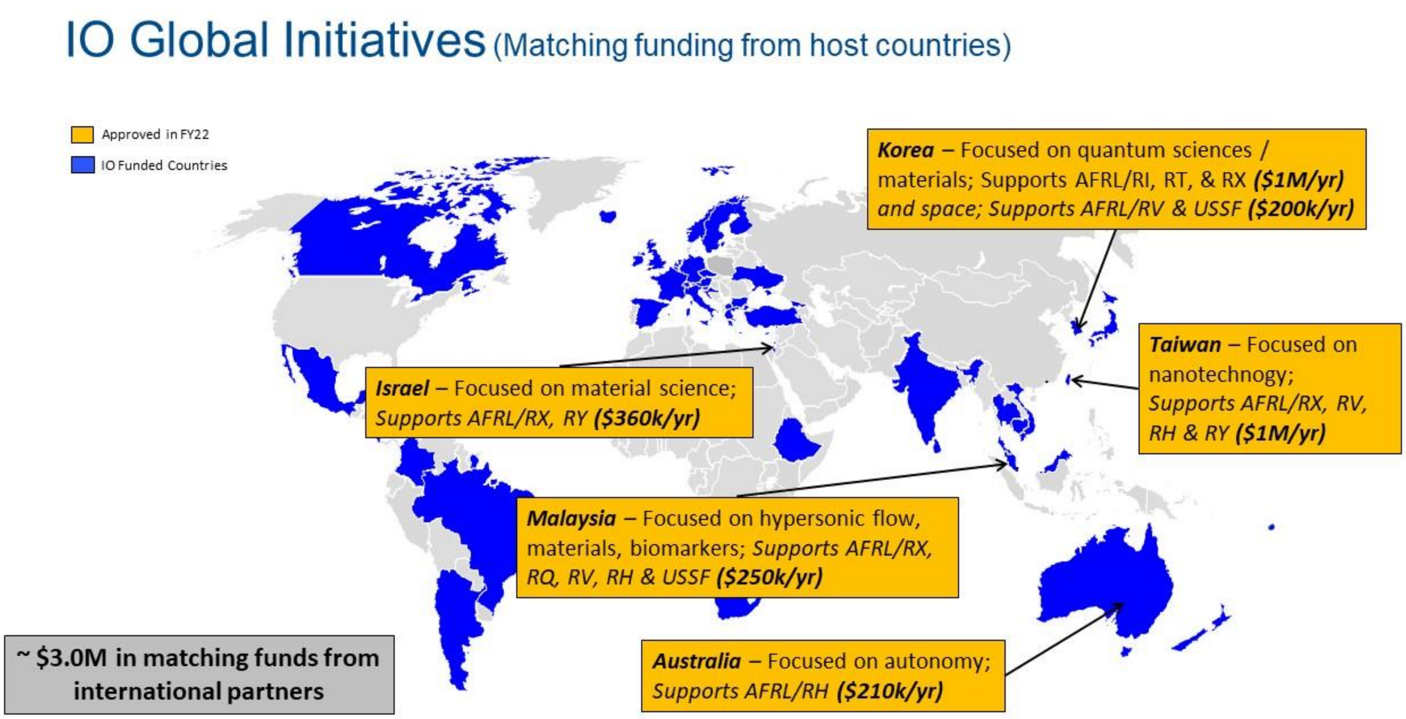
Principal Investigator: Prof. Don Pollacco, University of Warwick

LEO orbits are now being extensively used now that we have entered the era of the "mega-constellations". Low orbits filled with swarms of spacecraft can be used to gain some of the advantages of GEO orbits but with decreased latency. Hence, projects using LEO constellations are aiming to enable cost effective internet services over the complete globe and will be heavily used by the financial industry. Amongst the thousands of new satellites there will be opportunities for new actors to hide or at least disguise new spacecraft and their instrumentation.

This research experiment obtains high quality and high time resolution light curves of LEO objects and then uses sophisticated image analysis and signal processing techniques to probe the nature of the body and understand what confidence can be placed on these inferences. For this experiment the SuperWASP lens array on La Palma was utilized. This facility is an ultra-wide field imaging camera composed of 8 different optical tube assemblies (OTA) which can be manually changed to allow different amounts of field overlap. SuperWASP was designed to facilitate extremely accurate photometric brightness estimates. In this effort, 2000 lightcurves from 900 unique targets have already been obtained. This dataset will form the high-level statistical basis for machine learning analysis techniques which will be the subject of future efforts. Program Officer: Maj Grant Thomas, EOARD, Space Science

Country Initiatives

AFOSR International Offices support to expand the horizons of scientific knowledge through international collaboration in search of revolutionary basic research breakthroughs. The AFOSR international initiatives were highlighted by the chief-of-staff of the USAF as models for international scientific collaboration in the 2013 Global Horizons final report. These programs are often structured as team proposals consisting of a US partner and a foreign partner where the foreign country funds the foreign half of the team and AFOSR funds the US half of the team. The main focus is the exchange of information and ideas through the sharing of research data, joint publications, and teaching materials; through the exchanges of professors, students, and other professionals through jointly funded research grants. The initiative teams propose special synergy opportunities that build on the strong national investments of each nation that foster and promote collaboration in certain basic research areas. The scientific experts of each nation propose collaborations where together the scientists are able to accomplish more than they could accomplish separately. These efforts have historically shown a very strong return on investment and are a growing fraction of the investment portfolio of the AFOSR International Office.



Australian Autonomy Initiative

POC: Dr. Geoff Andersen, USAF and Lt Col Alan Lin, PhD, USSF

Both the US Air Force Office of Scientific Research (AFOSR) and Defence Science and Technology (DST) have a collective interest in the development of trusted autonomous systems. Building on substantial investment of the US and Australia in autonomy, this program produced premier collaborative research activities between the two countries. In order to continue to provide opportunities for scientists and engineers in both countries to collaborate in these emerging technology areas and to leverage their intellectual resources, AFOSR and DST offered a research initiative dedicated to the area of Trusted Autonomous Systems.

The US-AUS Autonomy Initiative (AAI) from 2014-2020 (FY15-FY19) was the first formal AFOSR country initiative program. Focused broadly on autonomy, one of three identified game changing technologies, the initiative organized 7 joint-projects. Each joint project included one US partner and one AUS partner. Three of the seven projects included a DoD or Australia Defence Science and Technology (DST) lab as one of the partners.

In 2020, AFOSR and DST established a follow-on US-AUS Autonomy Initiative focused on “Verification and Validation of Autonomous Systems” and “Human Machine Teaming” :

(A) Verification and Validation of Autonomous Systems. Research questions should address “how do we prove an autonomous system or an autonomous swarm will do what you want it to do?” and “how do you prove such systems will not do what you do not want it to do?” These questions implicitly include the need for explainability.

(B) Human-Machine Teaming. Future R&D must further integrate artificial intelligence & human cognitive models, advance human-agent feedback loops and intent inferencing, optimize trust/transparency, and advance sensor/data decision models. System design will need to address the human operator as part of the system, in various roles.

At the end of 2020 (FY21), AFOSR and DST jointly-awarded 3 projects out of 33 submissions (in no particular order):

Cognitive Trust-Based Task Assignment in Human-Machine Teaming

Chief Investigators: Prof. Chin-Teng Lin (University of Technology Sydney, Australia) and Prof. Tzyy-Ping Jung (University of California San Diego, USA)

As agents enabled by artificial intelligence (AI) are becoming ubiquitous worldwide, human-machine teaming (HMT) is gaining increasing attention [1-3]. Although considerable progress has been made in balancing the distribution of control authority between humans (H) and machines (M), there continues to be a limited understanding of the effects of differences in covert (internal) states between humans and machines on this control relationship and system performance. Covert states are usually associated with different levels of uncertainty stemming from the fact that the human mind, machine sensing, and interactive environments are nonstationary in nature. However, current tools for monitoring the relationship between system performance and covert states lack systematic, efficient and interpretable mechanisms. These problems result in a lack of reliable decision-making in HMT. This project aims to (1) develop a framework to extract and represent the covert state of humans and machines; and (2) effectively translate extracted information into trust metrics for cognitive trust-based task assignment in HMT for effective decision-making.

Verification and Synthesis of Fault-Tolerant Autonomous Systems

Chief Investigators: Prof. J.Y. Halpern (Cornell University, USA) and R. van der Meyden (University of New South Wales, Australia)

Safety- and mission-critical systems must be robust against failures and faults in their components, particularly when operating in physically harsh environments (battlespaces, space environments, extreme weather conditions or radioactive settings) or subject to cyber-attack. Moreover, when designing such systems, protocol designers need to take account of network topology, reliability properties of communication (message loss, delay, duplication, authentication), and the failure modes of components. Failure modes can range from crashes (or component destruction) to Byzantine faults (arising from electro-magnetic effects on hardware or cyber-attack), where a faulty component may send inconsistent messages to different parts to the system. In the autonomous systems context, the existing complexities are compounded by the need to take into account sensor models and knowledge of the physical environment in which the system needs to operate. There is a long-recognized need for formal verification in the development of systems in this area. The goal of this project is to provide tools for such formal verification, using epistemic logic, and specifically, knowledge-based programs, a high-level abstraction for the design of distributed protocols. Knowledge-based programs allow designers to (a) express their intent using formalizations of concepts that they often use intuitively but informally; (b) separate the key ideas underlying the protocol from the details of how the agent acquires and represents knowledge; (c) apply the same correctness proof in a wide variety of contexts (that may, e.g., vary in their assumptions about the environments in which agents operate); and (d) prove that protocols are optimal in the sense of taking actions at the earliest possible time. The time seems ripe for an assault on the problem of automatically synthesizing verified fault-tolerant distributed protocols from comprehensible high-level knowledge-based specifications.

A competency-aware multi-agent framework for human-machine teams in adversarial environments

Chief Investigators: Prof. Cindy Bethel (Mississippi State University, USA) and Prof. Richard Dazeley (Deakin University, Australia)

A joint effort will be performed through a collaboration between Deakin University in Australia and Mississippi State University in the United States. U.S. PIs, Bethel and Anderson, will work together with the Australian team members to investigate how future combat teams operating in adversarial environments will utilize trusted autonomous systems to achieve mission objectives, such as identifying, classifying, locating and suppressing threats while ensuring safety and survival of team members. To achieve this, humans and machines will work in teams, exploiting the unique potential of each team member in completing tasks with competing objectives. Our approach is a multi-objective, multi-agent, human-machine planning problem, understanding and explaining how agent actions impact goal attainment and how actions are inter-dependent between agents will assist command personnel to effectively plan, execute, and evaluate missions in complex environments, and support acceptance of trusted autonomous systems in defense teams. PI Bethel will investigate situations in which team-based operations where each team member must be able to develop a mental model of what other agents are planning and capable of achieving. The US team will develop rule-based and exemplar-based models of human decision-making derived from knowledge and expertise of human team members and through analysis of human decisions in specific contexts. These will support inclusion of other agents' capabilities and expected behaviors into planning problems. These cognitive models will also support representation of cognitive load and decision competency, to better capture the capability of team members to adapt behaviors in changing information contexts under mission constraints (e.g. time and risk). A significant challenge of this research is conflict resolution: determining whether the human or the autonomous system is most qualified to decide on the most appropriate action to take at critical decision points in the mission, given different constraints. A critical component of human behavior modeling is the ability for the human to maintain situation awareness and engagement to know when it is critical to intervene. Another aspect is to have a good understanding of the cognitive load of the human team member and how the activities of the multi-agent systems increase/decrease the cognitive load of the human team member. As trust in the multi-agent systems' decision-making capabilities increase the need to rely on the human-team member is expected to decrease; however, that human team member will need to remain engaged in the interactions as part of operational communication and to meet the desired operational outcomes. Once these models and systems are integrated, extensive user and field studies will be performed to validate the results of this research effort.

USAF/Taiwan Topological and Nanostructured Materials Synthesis and Discovery Country Initiative

IPOs: Dr. Todd Rushing and Dr. Jeremy Knopp

The US-Taiwan Nanoscience Program is one of the Air Force Office of Scientific Research's (AFOSR) International Research Initiatives. Since 2002, AFOSR has pioneered and perpetuated a prolific partnership with researchers in Taiwan - a world leader in technologies for materials, manufacturing, and electronics - focused on shaping and advancing the state of nanoscience research. PIs from US and Taiwan research institutions join forces for proposals that synergistically leverage their talents and resources for breakthrough discoveries. These bilateral investments nurture collaboration among elite scientists for fundamental discoveries enabling previously unattainable advancements in computation, communication, cryptography, sensing, optics, biodetection, automation, autonomy, and materials for space systems.

Starting in 2002, grants were provided to Taiwanese investigators to focus on basic research in specific nanoscience areas of interest as described by program managers at AFOSR or at the Air Force Research Lab (AFRL). In 2011, the program evolved to become a collaborative effort in research submission and funding. A US and Taiwanese investigator jointly submitted a research proposal for consideration, and each investigator was funded by their respective country's agency (Taiwan -- National Science Council, NSC; US – AFOSR). From FY 2011 to FY 2013, $600K USD/year was provided to US team members, and a total of eight collaborative grants were awarded. With the success of this Phase I of the USAF-Taiwan Nanoscience Program, the Taiwan Ministry of Science and Technology (MOST, formerly NSC) extended their National Nanoscience Program for an additional phase.

In FY15, a joint collaborative research proposal "rider" was attached to the Taiwan Innovation and Application of Nanoscience Thematic Program (IANTP) General Call for research proposals. Taiwan researchers whose proposals successfully passed MOST's highly selective evaluation process were then encouraged to submit collaborative research proposals with US researchers, which formed the basis for Phase II. Seven joint proposals were chosen by AFRL and DoD subject matter experts.

The US-Taiwan Phase II program was so successful, publishing forty-two journal papers, that a Phase III (FY18-FY21) was approved. Funding was increased on both sides to $100K USD/year per project. The focus of Phase III was on Nanostructured Materials for Sensing and Sustainment. A U.S. evaluation team consisting of AFRL, Army, and DARPA personnel collaborated with the Taiwan evaluation team to conduct a rigorous down-selection process resulting in ten funded projects in five concentration areas:

1. Novel multifunctional materials
2. Materials for quantum phenomenon
3. Flexible functional materials
4. Bio-inspired materials for sensing
5. Predictive functional materials

The Phase III kickoff meeting was held in Taipei, Taiwan December 10-11, 2018. In this kickoff meeting we were fortunate that attendees came from various AFRL Technical Directors to help steer the program. The first annual program review was held at the Hale Koa in Hawaii on December 10-11, 2019. The team was honored by the attendance of Dr. Minn-Tsong Lin (MOST

Director General of Department of Natural Sciences and Sustainable Development) at the kickoff meeting and by Col Brent Morris (AFOSR/IO Commander) at both events. Deputy Director of MOST, Dr. Dar-Bin Shieh, followed up by extending an invitation to visit MOST December 16th, 2019 to discuss possibilities for a future initiative.

Both parties introduced new personnel to lead the Initiative beginning in 2020. On the Taiwan, side long-time champion and lead Dr. Chia-Seng (Jason) Chang began transitioning his responsibilities for the Initiative to colleagues. Jason has been a valuable asset to the program, and continues to serve as a key advisor to the program. As of 2021, Yu-Ming Chang from National Taiwan University serves as Chair of the MOST nanotechnology program committee, and Dr. Tien-Ming Chuang serves as co-chair of the MOST-AFOSR program committee. On the US side, Dr. Todd Rushing, AOARD IPO for Materials, Chemistry & Nanoscience, joined Dr. Jeremy Knopp as co-Program Officer for the Initiative.

Facilitated by AFOSR personnel in Arlington and Tokyo, a comprehensive Phase III final program review was held virtually on 15-16 July, 2021. AFOSR's Director Dr. Shery Welsh and Chief Scientist Dr. William "Pat" Roach provided inspirational introductory remarks, followed by an excellent historical review of the US-Taiwan Initiative presented by Taiwan's influential Maw-Kuen "MK" Wu. The PIs from both sides of the ten collaborative projects presented research outcomes from the past three-year efforts. A book of abstracts summarizing the ten projects was prepared and shared with participants. Metrics were collected from each team to measure the productivity of the program in terms of publications, discoveries, patents, industry/USAF/DoD relationships, team collaboration synergy highlights, and follow-on awards enabled by the program. Input received from the researchers listed 101 publications, four patents, and seventeen awards resulting from the Phase III program. Data analytics conducted by the BRICC identified 136 publications acknowledging Taiwan Initiative funding since the start of 2018.

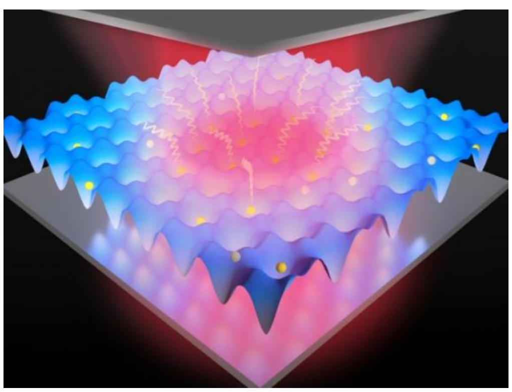
A great example of a phase 3 project is with Prof. Hui Deng of the University of Michigan and Prof. Lee Yi-Hsien of National Tsing Hua University titled “Scalable Single Photon Source Using CVD-Grown Monolayer Crystals on Nano-rod Lattices.” The project is focusing on the use of 2D materials for single photon emitters. Single photons (SPs) are a critical resource for quantum information, but remain limited in scalability, operating temperature, and heterogeneous integration. Atomically-thin 2D materials have emerged as a high-temperature SP source with unprecedented flexibility. The challenges include:

1) Poor yield and difficulty of integration using the conventional methods to create scalable, strain-induced single photon emitters in 2D materials
2) Difficulty to characterize the dimensionality of excitons in moiré lattices where separation between moiré cells are a few tens of nanometers

Progress in FY21 included the following exciting result:

Polaritons in a Moire Heterostructure - This is essentially the creation of a moiré quantum-dot-array polariton system, which may provide solutions to some of the long-standing difficulties in quantum photonics research leading to efficient and scalable semiconductor lasers. The co-existence of a giant nonlinearity and cooperative coupling of light, combined with the flexibility of tuning of the moire polaritons, suggests a pathway to scalable, strongly interacting photon systems that may allow exotic many-body quantum states and quantum information processing under practical conditions. Prof. Yi-Hsien Lee has been funded by AOARD in the past.

Read More: Nature 591, 61 (2021).



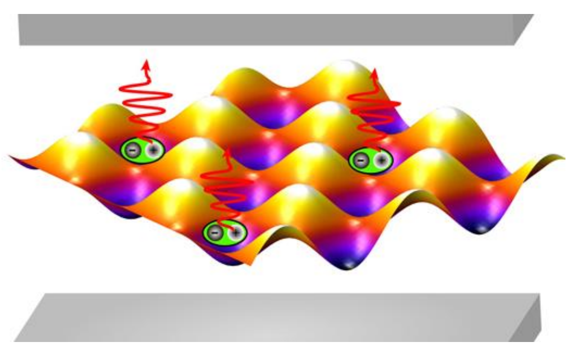


Figure: Moiré quantum dot array polaritons

In FY21, a wholesale team effort culminated in the launch of **Phase IV** of the Initiative, “Topological and Nanostructured Materials Synthesis and Discovery.” Subject matter experts from AFOSR, AFRL, and MOST collaborated to establish and define technical research thrusts that will stimulate future AF-relevant scientific discoveries. Led by AOARD, over forty subject matter experts from Taiwan MOST, AFOSR, AFRL TDs, US Army DEVCOM ITC-PAC, and NRL evaluated and selected projects from fifty-four entries in four thrust areas. By the end of FY21, AFOSR and MOST had each awarded $1M/yr for three years to fund their associated researchers across ten chosen projects (like in Phase III, the funding level is $100k/yr for each researcher; $100k/yr on the US side, and $100k/yr on the Taiwan side). As additional FY21 funding became available, AFOSR invested another $0.7M, funding both sides of two very promising projects, and the US side of three more.

The four technical research thrust areas as described in the Phase IV solicitation follow:

1. Topological and Qubit Materials: Electronic topological states in materials are protected from some types of perturbation due to novel ordering, termed “topological,” of their electron wave-functions. Enhanced coherence and the resulting robustness to perturbation makes these electronic states potentially useful for computation, communication, and sensing. Alternatively, qubit materials exploiting defects in solids have shown tremendous promise for low-noise sensors, unbreakable cryptography, and next-generation computing. In order to realize this promise, development of the fundamental and supporting technologies required to enable real-world applications is essential. The following are focus areas of interest:
    a. Theoretical approaches to topological states: New approaches are sought to predict new topological states and materials which host such states, and to describe known topological states. Because topological properties vanish at high temperatures in most topological materials, prediction and realization of high-temperature topological states in quantum materials are desirable.
    b. Synthesis, characterization and manipulation of materials with topological states: Fundamental understanding is sought regarding the relationships between properties of the topological state and growth parameters, as well as the relationships of the topological state to material point and extended defects. Discovery is also desirable regarding coupling and interactions between different topological states, as well as between topological states and other matter (e.g., magnetic materials, superconductors, etc.).
    c. Quantum sensing: New approaches are sought that can achieve higher sensitivity, the measurement of distinct quantities, or the characterization of higher order effects. Proposed concepts could include, but, are not limited to, the development of novel qubits, distributed sensing, or new sensing techniques.
    d. Improved coherence and entanglement: Quantum entanglement is fundamental to both networking and computation; however, modern qubits are limited in the number of nodes that can be entangled and operations that can be completed prior to decoherence. Concepts should seek to achieve long-lived coherence and entanglement between states through the development of novel state preparation techniques, faster and more robust entanglement approaches, novel qubits, qubit material refinement, phonon control, or alternative approaches.

2. Novel Multifunctional Materials: High-performance, multifunctional materials enable devices and components for intelligence, surveillance, and reconnaissance systems as well as modern information technology. Therefore, scientific advances in multifunctional materials are sought in the following focus areas:
    a. Novel electronic materials: The goal is to provide new functionalities or extend the performance and power handling in power, RF, and digital electronics applications.
    b. High-performance optoelectronics: New materials and concepts in optoelectronics are needed to advance applications in communication, optical sensing, and optical processing. A particular focus is on material hetero-integration for integrated photonics; i.e., on Si or other suitable semiconductor substrates.
    c. Novel materials beyond electronics/optoelectronics: There are emerging materials with operating mechanisms beyond using charged carriers and photons. For example, magnetism, spin wave, ferroelectricity, piezoelectricity, sound wave, plasmonics, etc.,

are all unconventional ways to carry and/or process information. Exploration of emerging materials using one or a combination of these mechanisms is desirable.

3. Novel Biomaterials and Interfaces: The focus is the design, synthesis, and characterization of bio-compatible/derived/ inspired materials with novel properties (e.g., surface chemistries, multifunction structural mechanics) capable of interfacing with natural or synthetic systems. Synthetic biology is poised to re-invigorate research areas such as pervasive, networked biosentinels for remote environmental sensing, but may also revolutionize how/what materials can be produced with targeted properties across length scales encompassing molecular building blocks to bulk materials. Characterization of these multifunctional structures in model systems (for instance, organ-on-a-chip) is necessary to confirm functionality in complex environments. Approaches to monitor the sensing event by hands-off means (e.g., RF, magnetic, etc.) will be critical to understanding potential transitions.
   a. Hybrid, interfaced, organic and inorganic systems for environmental sensing: Materials of interest include integrated biological polymers with semiconductor/electrically-active properties. Additionally, platforms are sought that integrate novel recognition elements like natural or artificially generated receptor-based systems for biomarker monitoring, capable of high-throughput, label-free characterization via multiplexed arrays that do not require intricate specificity (e.g., pattern-based signaling and matrix-based sensing outputs).
   b. Novel Materials: Materials are desired with new functionality/characteristics that arise from unique biology that current/traditional materials science and manufacturing research cannot address. Also of interest is the design/manufacture of sustainable, alternative (replacement) biomaterials.
   c. Bio-inspired material designs and assembly methods: Approaches are needed for making new materials outside the bounds of nature, e.g., engineering ribosomes to use new monomers, or going beyond ribosomes altogether. Other interest areas include sequence-encoded block co-polymers to include more orthogonal chemistry and high performance materials based on synthetic proteins.

4. Machine Learning Guided Materials Research: Matured machine learning tools have been useful in data automation, smart communication, design innovation, and autonomous decision making. Machine learning approaches are now being adapted for materials discovery and efficient materials design of complex constituents and functionality. Accuracy and adaptability of machine learning related to nanomaterials research is highly desired. Suggested focus areas for this topic follow:
   a. Machine learning for quantum materials: Meso-scale machine learning methodology is needed for training rules on defect influence on quantum response in nanomaterials.
   b. Design rules on 2-D materials heterostructure assembly: Fundamental understanding is needed with regards to interfacial effects of heterostructure assembly (spatial or thickness stacking) on electron, photon, phonon transport behavior.
   c. Machine learning for sensing materials: Physics-based machine learning rules are desired for defect design in 2-D materials for sensor performance (optical, thermal, electronic, or magnetic).
   d. Machine learning for hybrid materials: 2-D materials hybridization design rules are sought for targeted properties.

A complete listing of the Phase IV projects is provided below:

US -Taiwan Nanoscience Projects (Phase IV)

Phase IV: 2021-2024 **Program Officers: Dr. Todd Rushing and Dr. Jeremy Knopp**

Title	Institution	Country	Principal Investigator
Machine Learning Guided Defect Study of Electrochemical Nanostructured Materials for the Neuromorphic Application	UCSD	US	Meng, Shirley
Field-effect Tunable Titanium Nitride Epsilon-Near-Zero Metasurfaces for Dynamic Manipulation of Thermal Emission	UC Irvine Academia Sinica	US Taiwan	Lee, Howard Gwo, Felix
Novel Topological and Qubit Materials Platforms Created by Engineered hBN Substrates	MIT National Cheng Kung Univ	US Taiwan	Oliver, William Chen, Tse-Ming
Topology and Magnetism in Chiral Crystals	Boston College National Sun Yat-sen Univ	US Taiwan	Tafti, Fazel Huang, Shin-Ming
Magnetic Topological Critical Materials	Univ Alabama-Birmingham National Yang Ming Chiao Tung Univ	US Taiwan	Chen, Cheng-Chien Lin, Jiunn-Yuan
Engineering Magnetic Topological Insulator/ Topological Insulator Superlattices as Novel Topological Quantum Materials	Univ Texas-Austin National Tsing Hua Univ	US Taiwan	Shih, Chih-Kang Hsu, Pin-Jui
Multi-Functional van der Waals Superlattices for Integrated Photonics	Univ Pennsylvania Academia Sinica/NTU	US Taiwan	Jariwala, Deep Lu, Yu-Jung
Topological Quantum Circuit Based on 2-D Weyl-Semiconductor/Superconductor Junction	Purdue	US	Wu, Wenzhuo
Active Learning-Enabled Brain-On-A-Chip Design for Neural Drug Development	Univ Maryland-College Park National Chung Hsing Univ	US Taiwan	Chen, Po-Yen Lai, Ping-Shan
Moiré Quantum Dot Array Polaritons for Ultra-Low Energy Optoelectronics	Univ Michigan	US	Deng, Hui
A Spintronic and Photonic Transducer Based on Layered Two-dimensional Magnetic Materials: Controlling Light Emission	Univ Texas-Austin Academia Sinica	US Taiwan	Li, Elaine Lee, Shang-Fan
Biofabricated Nanoconfined Materials and Devices for Bio-recognition and Sensing	Univ Virginia Academia Sinica	US Taiwan	Swami, Nathan Chou, Chia-Fu
Material and Device Engineering of Ga2O3 RF Electronics	Univ Massachusetts National Cheng Kung Univ	US Taiwan	Wong, Man Hoi Li, Jian V.
Exploring and Exploiting Transient Phase Diagrams in Electronic Materials	AFRL/RXAS National Taiwan Univ	US Taiwan	Glavin, Nicholas Hofmann, Mario
Layered Topological and Functional Materials: Single Crystal Synthesis, Characterizations, and Applications	AFRL/RXAP National Cheng Kung Univ	US Taiwan	Susner, Michael Lue, Chin-Shan

US-Malaysia Science and Technologies Initiative

The U.S. Air Force Research Laboratory's Air Force Office of Scientific Research (AFRL/AFOSR) and the Ministry of Higher Education in Malaysia launched the US-Malaysia Science and Technology Initiative in the year 2021. This cooperation is basic research within the scope of the current AFOSR BAA that includes Industrial Technology, Artificial Intelligence (AI), Materials Science, and Aerospace Propulsion basic research of crucial importance to both the United States and Malaysia. The primary objective is to establish basic research collaborations between AFOSR and the Ministry of Higher Education to make contributions to basic research in Artificial Intelligence (AI), Materials Science, Aerospace Propulsion, cyber-security, and other basic research areas as described in AFOSR's current BAA. The successful development of these technologies will foster greater collaboration between universities in the USA and Malaysia, and will also provide a foundation for government-to- government agreements in applied research and more advanced programs.

Research objectives for this initiative are as follows: Artificial Intelligence (AI), Materials Science, Aerospace Propulsion sought but not limited to include: (1) Investigations of novel research in natural materials such as bio-interface studies in natural GREEN composite materials systems, (2) Biomarkers for Decompression Sickness (DCS) in high altitude (3) hypersonic flow control, and (4) optimization and multi-scale modeling. Additional research concentration areas of this program include the understanding and predictive design of new materials whose atomic and molecular structure, bonds, and defects can facilitate superb quantum behavior (i.e. coherence, entanglement, spin dynamics, etc.); study of effects from influences such to help realize these objectives the participants intend to:

a. Exchange information in the domain of Industrial Technology, Innovation for Sustainable Tomorrow, Artificial Intelligence (AI), Materials Science, Aerospace Propulsion, and other basic research areas in described in AFOSR's current BAA through the sharing of publications, videos, bibliographies, and teaching materials; through the exchanges of professors, specialists, students, and other professionals; through workshops, conferences, seminars, and jointly funded research grants; and through other initiatives that foster and promote collaboration in basic research.

b. Jointly fund up to 3-year grants in Malaysian universities and/or research institutes who are collaborating with US universities and/or research institutes on innovative ideas and proposed initiatives related to basic research.

US Malaysia Science and Technology Initiative: 2021-2024

Program Officers: Dr. Tony Kim, and Dr. Jeremy Knopp

Background: A US-Malaysia Initiative on Science & Technology was initially proposed during a visit to the Ministry of Higher Education of Malaysia and the National Defense University in Malaysia during 2019-2020.

International Program Officers from the AOARD office visited the University of Malaya in February of 2019 and met with faculty members from computer science, computer engineering, and information technology. An overview of AOARD was presented during the meeting and discussed the Grant/CSP/WOS programs and the processes associated with each of them. The entire faculty were very excited and in-depth questions and discussions regarding how basic research is defined and the process for applying for grants were held. One of the faculty members was from the University Kfbangsaan Malaysia and he had a draft white paper that was discussed during our meeting on information technology. It seems most of the faculty members were interested in the computer technology. On the following day, we visited the International Relations Division of Ministry of Higher Education and met with Principal Assistant Secretary (Ikhwan Nasir Bin Abu Hanipah) and Director (Prof. Raha BT Abdul Rahim). Once again, the AOARD international program officers presented an overview of AFRL/AFOSR/AOARD and all the programs we have in the AOARD office for engage with universities in the IndoPacific region. Furthermore, the International Initiative program that the AOARD office manages was described. The director was very excited about the initiative program and at the same time Director told us that the Malaysia government is investing in basic science and would be very interested in the potential initiative program with the AOARD office. In the afternoon of the same day, we visited the National Defense University of Malaysia and met with the commander (Lt. Gen), Deputy Vice chancellor, Director, and Dean of Faculty of Defense Science and Technology with other faculty members from the university. An overview of the AOARD office and grant opportunities were presented, and a discussion of the basic research topics for several areas such as computer science, electrical & computer engineering, and information technology occurred. There was high interest in computer science in the areas of processing, machine learning, AI, data mining, and data fusion. This TDY and visits to Ministry of education and Defense University was possible due to Dr. Akira Namatame, who managed a project with Professor Rafidah Noor from the University of Malaya, who's intern introduced us to both the Ministry of Education and the Defense University. This TDY definitely showed us how important it is that we maintain constant vigilance with respect to -awareness, engagements, and relationship building in international.

<u>Malaysia Visit</u>

Ministry of Higher Education of Malaysia with Principal Assistant Secretary
19 Feb 2019

National Defense University of Malaysia with Commander (Lt. Gen)
19 Feb 2019

National Defense University of Malaysia
Feb 2020

12 February 2020: AOARD program officers visited the National Defense University of Malaysia, Kuala Lumpur, Malaysia. Dr. Jeremy Knopp, Maj. Chris Vergien, and Dr. Tony Kim visited Deputy Vice-Chancellor Office of Research and Innovation (Prof. Azizi Bin Miskon) and professors from several other engineering departments. This meeting was to follow up on a meeting from the previous year to discuss the R&D proposal they submitted. The AOARD office is supporting two projects; one in the mechanical of wrap density composite materials, and the other one in biomarker sensor development. The relationship we built provides a foundation of the potential collaboration and future US-Malaysia Initiative program.

List of the 6 projects were selected/awarded in 2021

1. **Mechanism of Warp Density and delamination on ballistic impact properties of laminated hybrid Bamboo/E-GLASS/ EPOXY Natural GREEN Composites.** Professor Aidy Ali from the National Defense University of Malaysia (UPNM) proposed the study to identify the fundamental mechanisms of warp weft density on the performance of bamboo composites towards mechanical delamination, mechanical fatigue and fracture and the effect of aging of natural composites towards environmental attack. Recent study and development of bamboo composites show the bamboo have superior strength when it is in laminated forms.

   In Year 2018, Aidy et al successfully developed and test a hybrid bamboo/E Glass/ UP hybrid composites. The developed composites were tested and reach the level III of National Institute of Justice (NU) standards. The fracture toughness found were similar with steel alloy. This hybrid bamboo is planned to be construction materials for high load transfer and antiballistic engineering components that promotes green technology as well as functioning for defenses. The applications of these new composites could be a key to the new construction of light well high structural integrity of ship hull for the naval applications. This research requires strong fundamental understanding on the mechanisms of bamboo composites strength from its waft weft density, laminated arrangement, processing parameters and treatment in order to move forward and realize them into practice.

   Unsaturated Polyester (UP), Woven Bamboo fiber (WB) and Woven E-Glass Fiber (WEG) are the materials used for this study. The bamboo was Gigantochloa Scortechinii (Bu/uh Semon tan) which was collected from Kampung Bukit La rang in Malacca, Malaysia. (See Figure 1.) The woven properties studied by several waft and weft density until we reach the optimal performance of these composites. (See Figure 2). Having developed, the bamboo will be tested using standard tests of V50 and NU as shown in Figure 3.

Figure 1. Extraction of the bamboo and treatments

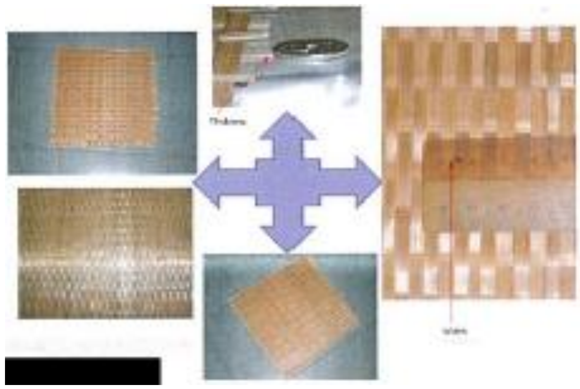


Figure 2. The waft and weft density effect, the proposed study on how to improve the woven properties.

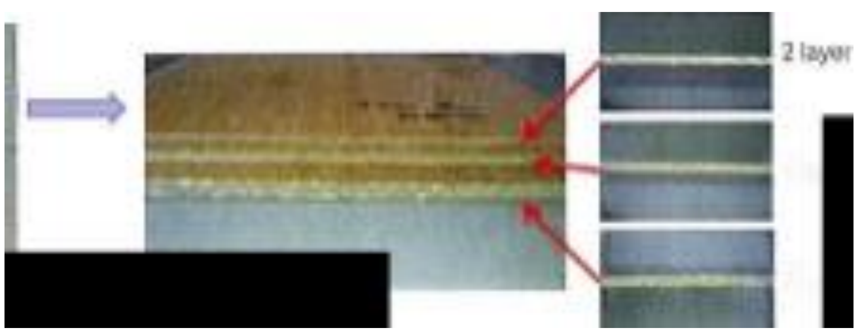
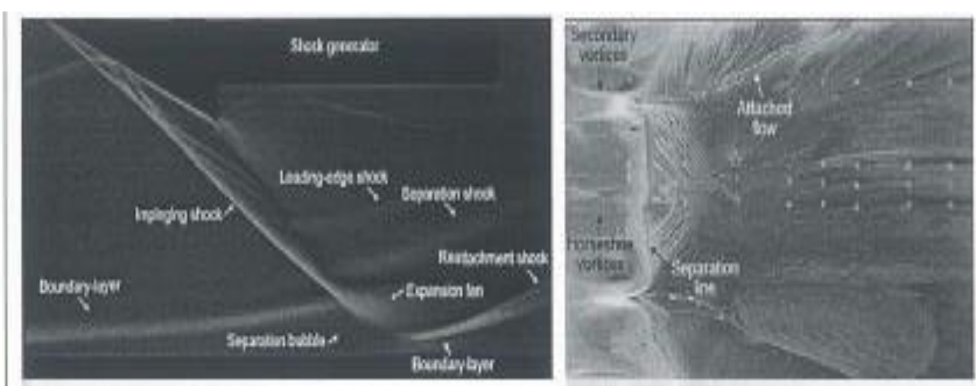


Figure 3. Fabrication and Shooting V50, NIJ tests.

2. **Shock Wave -Boundary Layer Interaction Control in Mach 5 Hypersonic Flow using Combined Active Flow Control.** Professor Mohd Rashdan from the National Defense University of Malaysia (UPNM) proposed to investigate, optimized designs, and configurations of the combined active flow control mechanism, which will contribute to the design of future high-speed air breathing propulsion system and re-entry vehicles that delivers better performance. Understanding the SBLI phenomenon and the control methods will also reduce the risk of accidents associated with both space and high-speed air-breathing vehicles. From the previous investigations conducted on both passive and active techniques, the boundary layer separation region was not able to be eliminated entirely. The flow control devices only managed to decrease the size of the separation region. Therefore, the aim of this study is to combine different active flow control mechanisms such as plasma discharge, jet and suction at hypersonic Mach 5 flow to overcome this problem effectively and reduce the size of separation region significantly. This study will also propose the optimized configurations involving all three techniques and this will be achieved by carrying out experimental studies using the hypersonic wind tunnel at the University of Manchester facilities.

In the initial stage of this project, the fabrications of the all the models that will be tested will be done in Malaysia, using the CNC facilities at UPNM. This involves a flat plate with stands and various models of active flow control mechanisms; plasma discharge, jet and suction. The models will then be tested in the hypersonic wind tunnel facilities at the University of Manchester UK. The experiments will involve the use of state-of-the-art flow diagnostics tools such as Pressure Sensitive Paints (PSP), Particle Image Velocimetry (PIV), high-speed colored schlieren and surface flow visualization (refer Figure 1). From the experiments, the flow physics of the combined active flow control devices and the improvements introduced will be visualized from the discrete and field surface pressure measurements, flow velocity vectors and shock wave colored schlieren images. The geometries and positions of the combined active flow control mechanism will be optimized in this investigation, to obtain the most significant reduction in the size of the separation affected area due to SWTBLI.



Left: Coloured schlieren of SBLI phenomenon in Mach 5. Right: Surface oil flow visualization showing the separation and attached flow region in the interaction area.

3. **Ascertaining the importance of biomarker and imaging modality in identifying the risk of Decompression Sickness (DCS) in high altitude.** Professor Shazreen Shaharuddin from the National Defense University of Malaysia (UPNM) proposed to investigate the potential of fluorescent sensors of hypoxia in detecting low Oxygen tension that could lead to hypoxia due long space flight at high altitude. The exploitation of these new technology detection would promise a novel potential role in detect and prevent the risk of developing hypoxia which can cause poor prognosis in the future of the air crews. There are three main objectives of this investigation related to the potential of fluorescent sensors of hypoxia as a diagnostic tool in detecting hypoxia at high altitude:

- To determine the specificity and validating of the fluorescent sensors of hypoxia in detecting physiological changes of biomarker of HIF-1α protein at high altitude.
- To determine the effectiveness of the fluorescent sensors of hypoxia in detect the onset of cognitive impairment due to lack of oxygen supply to brain by using the cognitive assessment on an air crews after 8 hours of flight.
- To develop the threshold values using the fluorescent sensors of hypoxia in detecting the risk of hypoxia.

4. **Investigation of the emission decay rate and charge kinetic in air-stable mixed-cation FAxMA1-xPbI3 perovskite solar cell with incorporation of organic long persistent luminescence.**
Professor Jun HIeng Kiat from the University Tunku Abdul Rahman in Malaysia is to investigating the of the emission decay rate and charge kinetic in air-stable mixed-cation FAxMA1-xPbI3 perovskite solar cell with incorporation of organic long persistent luminescence. PI will be collaborating with Professor Tan Tai Nguyen from Tra Vinh University from Vietnam for this research.

The objective of this research are as follows:
(a) If the incorporation of the organic LPL into the perovskite solar cell module can generate sufficient power under dark condition.
(b) If there's correlation between the amounts of organic LPL materials, architecture of the solar cell module and the performance of the solar cell module.

Significance/ relevance:
• New finding and observation on the efficiency of all-day perovskite solar cell with the incorporation of organic LPL as well as data/knowledge of improved emission decay rate of modified organic LPL for the application in photovoltaic.
• Publication in at least 2 ISI papers in Tier 1 and/or 2 journals such as Solar Energy Materials and Solar Cells, Energy and Environmental Science, and Solar Energy.
• This research would also enable the team to develop a low-cost and high performance all-day photovoltaic that may be able to be up scaled in the near future.

5. **Interactive Machine Learning based on Deep Reinforcement Learning and Generative Adversarial Network Hybrid for Digital Twin**

Professor Nurfadhlina Mohd Sharef of University Putra Malaysia is focusing on an interactive machine learning (iML) approach based on the hybrid between DRL and generative adversarial network (GAN) for asset maintenance planning of a digital twin (DT) system.

The challenges include:
1) To facilitate the asset's health monitoring and prognostics so human can plan for asset maintenance intervention.
2) To learn semi-autonomously the schedule using DRL and GAN

6. **Context-aware Vertical Handover for reliable 5G and Beyond Wireless Heterogeneous Networks with Embedded Generative Adversarial Network and Reinforced Bayesian Network.**

Professor Asma Abu-Samah of University Kebangssan Malaysia is developing a new model to select the optimal network to which user equipment (UE) in Heterogeneous networks may be handed over based on the different context of the UE.

The challenges include:
1) Minimizing energy consumption and heavier signal loads based on embedded-GAN dataset 2) Optimizing energy consumption based on the selection of the handover over using reinforced Bayesian network.

US-Korea Quantum Information Science and Technologies Initiative

The U.S. Air Force Research Laboratory's Air Force Office of Scientific Research (AFRL/AFOSR), the National Research Foundation of Korea (NRF), and the Institute of Information & Communications Technology Planning & Evaluation (IITP) announced a joint solicitation for research grants in breakthrough quantum information science and technologies in year 2021. This solicitation is part of an ongoing partnership between Korean institutions, NRF and IITP, and the Department of Defense. For the last 11 years the three organizations have worked together supporting basic scientific research efforts in key disciplines. In order to continue to provide opportunities for scientists and engineers in both countries to collaborate in these emerging technology areas and to leverage their intellectual resources, AFOSR's Asian Office of Aerospace Research & Development (AOARD), NRF and IITP have teamed to co-fund a program in quantum information science and technologies.

The proposed work is expected to utilize non-classical physical resources to develop beyond-classical capabilities in imaging, sensing and precision measurements, information processing and transfer, or simulation and discovery of complex materials. Research topics of interest in this program include the following broad areas: quantum communications and networks, quantum repeaters, quantum information processing, and quantum computing/simulation; and fundamental studies in support of this research area, such as fundamental investigations of the creation, manipulation, and characterization of entanglement, highly entangled states, dissipation engineering, quantum control techniques, new types of qubit development, and coherent state transfer between different types of qubits.

Additional research concentrations areas of this program include the understanding and predictive design of new materials whose atomic and molecular structure, bonds, and defects can facilitate superb quantum behavior (i.e. coherence, entanglement, spin dynamics, etc.); study of effects from influences such as elastic properties, vibrations, surfaces, and interfaces on the desired quantum (non-classical) behavior of the material; and exploitation of materials properties and phenomenon to mitigate sources of decoherence and enhance material performance in quantum information applications.

More specific scientific focus areas under this collaboration are:

- Integrated photonics for quantum technologies
- Hybrid quantum systems for quantum information science
- Single photon sources for quantum information applications
- Solid-state qubits
- Quantum material synthesis for quantum information applications
- Quantum simulator
- Quantum algorithms

KOREA-US QUANTUM INFORMATION SCIENCE AND TECHNOLOGIES INITIATIVE: 2021-2024

Program Officers: Dr. Tony Kim, and Lt Col Mike Richards

Background: A US-Korea Regional Initiative for Quantum Information Science (QiS) was initially proposed on 28 Nov 2018 at the US-Korea JST Workshop from the National Research Foundation Korea. As a follow-up, AOARD discussed possible areas of research with NRF during several site visits to Korea that collimated in a formal workshop hosted by Korea on 11 June 2019. During this workshop, Korea presented their strategic plan (attached slides) for Korea in Quantum Computing. Korea has a national plan (2019-2023) to develop some of the core quantum computing technology with a goal of 5-qubit quantum computer demonstration by 2023.

Although it is not the goal on the US side to develop a quantum computer, there are critical technologies that overlap, which benefit both countries. Accordingly, supporting synergistic teams of US and Korean Scientists to make a number of research breakthroughs is timely.

The collaborative goal is to work with one Korean Government agency funded by the Ministry of Science and Technology (MSIT), the National Research Foundation (NRF), to solicit, identify, and fund and evaluate basic research projects with potential for future defense applications.

AFRL, and NRF Scientists: To both maximize technical cooperation and advancement of scientific results towards useful technologies, we plan to apply two frameworks.

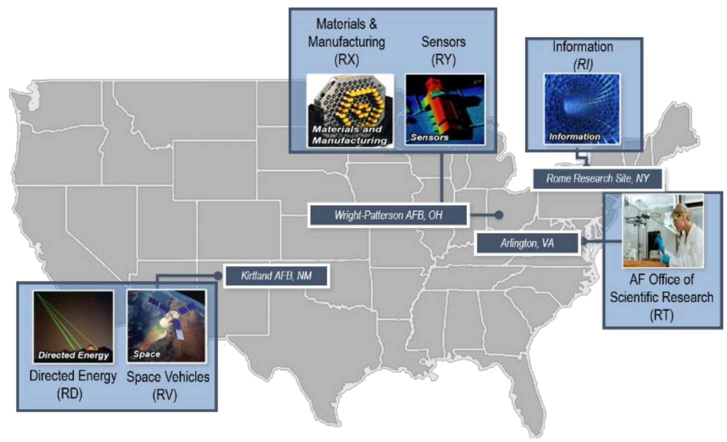
1) NRF. First, the previously established framework in which a collaborative teams of US and Korean university professors were separately funded by AFOSR and MSIT through NRF. Collaborations between US universities and Korean Universities remain important to both nations, and this process is the primary vehicle for advancing this effort.

2) For the US-side of the collaborations at AFRL, we expect for each project a 50/50 cost share between AFOSR & the TDs. If the research topics align with current or planned in-house TD research activities and their proposal is selected, the TD researcher and their appropriate leadership would be expected to allocate internal funds in the amount of 50% of the US portion of the proposed US-Korea joint effort for the length of the effort. The remaining 50% of the US portion would be awarded by AFOSR to the TD researcher in form of an LRIR or similar transfer of funds.
3) For the Korean portion of the proposed US-Korean effort, the funding would be provided by MSIT and be approximately equal to the US portion.

From the Korean and US perspective, this arrangement has the potential to continue the development of impactful fundamental understanding, leverage international scientific knowledge, and improve the transition of this fundamental understanding toward important societal needs. From the US government laboratory (TD) perspective, it provides a tripling of resources within an area of technical interest, leveraging top international talent in Korea, the strengthening of fundamental understanding, and the cultivation of collaborative relationships.

Selection was based upon

- Technical merits of the proposed research and development
- Potential relationship of the proposed research and development to DoD missions
- The unique synergy enabled by the US-Korean collaboration



List of the 10 projects in three quantum research areas were selected/awarded between August-October 2021

		US PI				Korea PI	
Project Title	US	Last Name	First Name	Quantum Topic	Korea	Last Name	First Name
Strained Moiré Excitons in van der Waals Heterostructures	University of Illinois at Urbana-Champaign	Nam	SungWoo	Quantum Materials	Korea University	Park	Hong-Gyu
Engineering Exceptional Points in All-On-Chip Hybrid Quantum Devices	Auburn University	Li	Peng	Quantum Materials	Ewha Womans University	Kim	Tae Hee
Quantum Simulation using Moiré Exciton-Polaritons	Graduate Center - CUNY	Menon	Vinod	Quantum Materials	Kyung Hee University	Kim	Young-Duck
Hybrid Quantum Algorithms for Quantum Many-body Physics	Virginia Tech	Scarola	Vito	Quantum Computing	Korea Institute for Advanced Study (KIAS)	Park	Kwon
Towards a new quantum platform based on ultracold molecules	Harvard University	Doyle	John	Quantum Computing	Korea University	Chae	Eunmi
Mechanically Modulated Microwave Circulator using Cryogenic-MEMS Switches	Purdue University	Bhave	Sunil	Quantum Computing	KAIST	Yoon	Jun-Bo
Nanoscale Quantum Emitters Integrated by All-fiber Optofluidics	University of Colorado Boulder	Sun	Shuo	Quantum Information / Communication	Yonsei University	Oh	Kyunghwan
A metasurface-enabled high-brightness high-indistinguishability single photon source at 1.55 μm	Pennsylvania State University	Ni	Xingjie	Quantum Information / Communication	Chungnam National University	Lee	Donghan
Resonators to Ultra-Coherent Spin Ensembles for Higher Efficiency Quantum Memories	Boston College	Zhou	Brian	Quantum Information / Communication	DGIST	Jung	Minkyung
Waveguide-coupled Interlayer Exciton Condensation LED in 2D Heterostructures for Quantum Optics Applications	Harvard University	Kim	Philip	Quantum Information / Communication	Chungnam National University	Yu	Young-Jun

MSIT-AFOSR Korea Programmable Materials and Next Generation Nanosystems

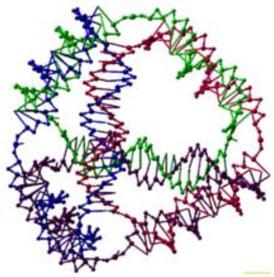
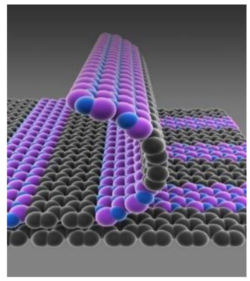
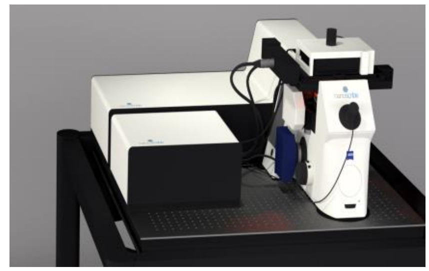
Purpose: Information on the US – Korea International Initiative on Materials of the Air Force Office of Scientific Research (AFOSR) International Office (IO) and Korean National Research Foundation (NRF).

Background on AFOSR/AOARD nanoscience efforts in Korea: The truly collaborative program among US and Korean PIs, the Tri-Service, and Korean research institutions has led to many research accomplishments. Both the US and Korea have made a substantial investment in nanotechnology over the past several years, and the same trend is expected to continue into the near future. In order to provide an opportunity for scientists and engineers in both countries to collaborate particularly in the areas of "nanostructured materials," "nanoelectronics" and "nano-biotechnology," AFOSR began supporting a series of US-Korea Workshops since 2002. As a result of these interactions, 17 exploratory research grants were arranged for a number of universities in Korea in 2005 under the AFOSR Nanoscience Initiative. Among them, 4 research grants were implemented with full matching support from Korea. In 2007, strong support from Korea and AFOSR led to the inauguration of a new Initiative for Nano-Bio-Information Technology (NBIT) Convergence with 1:1 matching support from two agencies. As a result, a total of 10 research projects was established for this Phase I (2007-2010) involving selected teams of researchers from premier research universities in the US and Korea. Three of the Phase I projects were continued along with six new ones forming a total of nine collaborative research grants for Phase II (2010-2013), in which Korea National Research Foundation funded the Korean PIs and DoD (AFOSR and US Army International Technology Center - Pacific) funded the US PIs.

Phase IV Nanotechnology US-Korean Initiative: As a result, in FY18, a new program "MSIT-AFOSR Korea Programmable Materials and Next Generation Nanosystems" was initiated which is substantially larger than previous programs. The technical scope of the program has been refined, and the new program also allows for participation by AFRL researchers.

The truly collaborative program among US and Korean PIs, the Tri-Service, and Korean research institutions has led to many research accomplishments. The two new topics are:

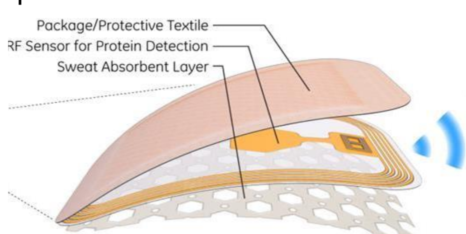
(A) Programmable Materials: Fundamental understanding about materials that couple sensing, actuation, and communication into an integrated additive construct whose response can be "programmed" to give a predictable response is desired. The additive construct can incorporation materials of different classes and/or widely varying properties (mechanical, thermal, viscous) and involve tailored interfaces and hierarchical structures of multiple scales. However, the "programmed" information should reside within the material state rather than externally applied or within a formal device (i.e. material = programmed information). Fundamental understanding of additive constructs which show a large range of programmability, a large or diverse range of response, or the ability to autonomously or progressively improve materials programming via subsequent learning cycles is of particular interest. Two key elements of this effort are considered to be (1) "Materials by Design" to achieve programming, response, and communication and (2) "Reactive Printing" for the rapid and controlled assembly of the additive construct through which the programmable material is utilized.

Materials by Design

Reactive Printing

(B) Next Generation Nanosystems: Substantial effort and understanding regarding nanosystems has been achieved over the past several decades of research effort including by the former US-Korea NBIT effort. Two specific areas of interest include (1) "Man-Machine Interface" in which nanosystems help to sense, assess, or augment human performance with miniaturized and flexible devices based on integrated nanosystems for such applications a wearable electronics, soft-robotics, battlefield acoustics, and manufacturing process control and (2) "Integrated Flexible Power" in which nanosystems help to store and harvest energy in agile and novel form factors that can conform to the shape of the human body, vehicle, manufacturing processing, or a morphing shape.




Man-Machine Interface

Integrated Flexible Power

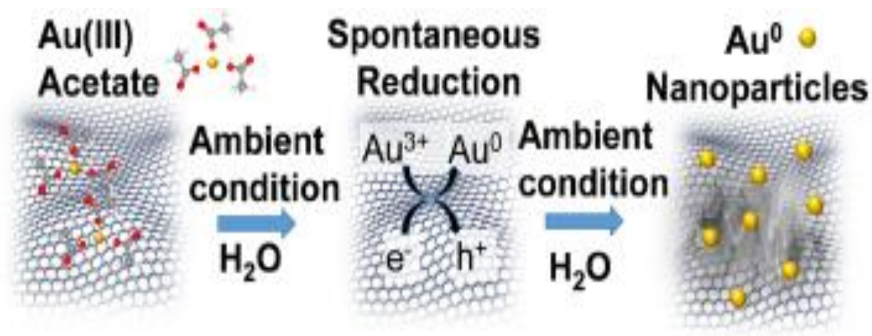
Current phase IV projects (2018-2021): Six out of 45 white paper have been selected to participate in the MSIT-AFOSR Korea in the Programmable Materials and Next Generation Nanosystems.

Title	Location	Country	PI
1. Mechanically robust and photo-reconfigurable epoxy nanocomposite by dynamic covalent reaction	*AFRL/RX* *Hanyang, Univ*	US Korea	Dhriti Nepal Young Jong Kang
2. In situ 3D electrochemical deposition of conductive poly (dopamine) composites in living tissues for bio-compatible man-machine interface.	*Delaware Univ* *Inha Univ*	US Korea	David Martin Bong Sup Shim
3. Programming for graphene properties via defect design and characterization	*AFRL/RX* *Hanyang Univ*	US Korea	Ruth Pachter Park, Won Il
4. Bio-integrated sensor patch comprising semiconducting silicon nanoneedles for intratissue and intracellular recording.	*Purdue Univ* *Hanyang Univ*	US Korea	Lee, Chi Hwan Kim, Dong Rip
5. Reversible reconfiguration 3D micro and nano photonic devices by magnetically programmable polymeric composites.	*South Florida Univ* *Inha Univ*	US Korea	Jianfeng Zhou J.J. Wie
6. Integrated flexible energy systems based on two (2D) dimensional materials	N. Texas Univ. SKKU Univ	US Korea	Wonbong Choi Hyunjung Shin

Final Program Review:

June 2021: AOARD and National Research Foundation (NRF) Korea conducted a virtual review of the US/Korean Program on Programmable Materials and Next Generation Nanosystems. Dr. Tony Kim (AOARD) and Dr. Chan Sup Shin (NRF) hosted 2 day long web conference with six teams from US and Korea to presented final year research accomplishment & achievement. All the research is focused on Programmable materials and Nanoscale materials. Both US and Korea research teams continuously collaborated during the COVID-19 by monthly video conferences, exchange of data & information, and the research was not delayed under these difficult circumstances. Tremendous accomplishments in the form of journal papers, patents, and presentations of their findings were collected. These metrics of R&D productivity will be analyzed using data analytics and an annual report will be published for this program at a later time. Program Manager (PM): Dr. Tony Kim, AOARD

Mechanically robust and photo-reconfigurable epoxy nanocomposite by dynamic covalent reaction. (Hanyang University & AFRL/RX)



To develop a novel structural composite which can be repaired via a light source (switch) and lightweight, strong, self-healing, multifunctional composites.

Accomplishments & Status:

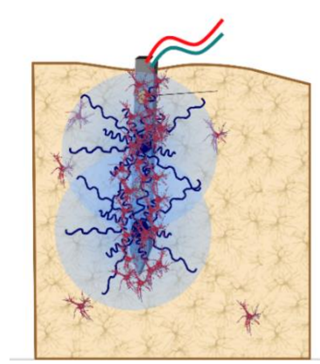
- Successfully modified graphite with AuNP
- Developed *in-situ* monitoring of reaction with FTIR
- Multicale modeling in progress
- Monthly meeting scheduled with Dr. Kang (Hanyang)

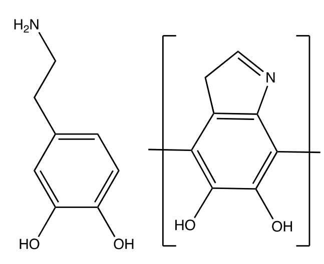
Publication:

ACS Applied nano materials

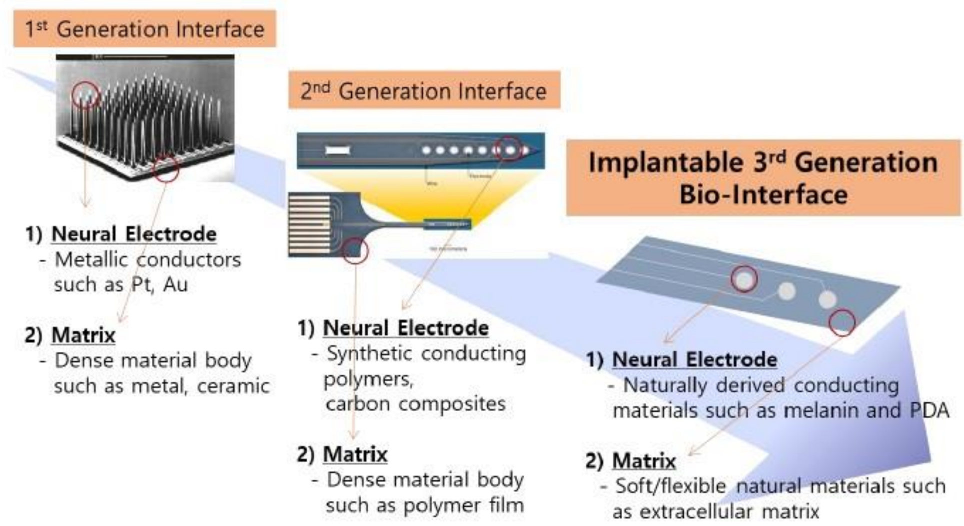
In Situ 3D Electrochemical Deposition of Conductive Poly (dopamine) in Living Tissue for Biocompatible Man-Machine Interfaces. (Inha U.& Delware U)

Project Vision: In the ultimate vision of implanting a computer to human body by seamless, stable, reliable, and functional biotic –abiotic interfaces, our approach is to exploit state-of-the-art materials design, synthesis, and characterization capabilities.





To improve materials for the direct, long term integration of biomedical devices with humans. Create conjugated polymers from all-natural precursors, compare performance to synthetic polythiophenes used previously stable, directly integrated biomedical electronic devices with humans.



BioInterfacing Materials without Foreign Body Reactions

1) **Electrochemical conductive polydopamine (PDA)** synthesis
2) **Biocompatible neural interfaces** by **in situ 3D structures of PDA**

<u>Accomplishments:</u>
12 papers published:

- M Kim, B Shim, R Iezzi, DC Martin, Frontiers in Chemistry 7, 234, 2019S Lee, T Eom, M Kim, S Yang, B Shim, ElectrochimicaActa, In press
- T Eom, J Jeon, S Lee, K Woo, J Heo, DC Martin, J Wie, B Shim, Particle & Particle Characterization Systems, 36(10), 1900166, 2019
- M Kim, B Shim, R Iezzi, DC Martin, Frontiers in Chemistry 7, 234, 2019
- S Lee, T Eom, M Kim, S Yang, B Shim, ElectrochimicaActa, 313, 79-90, 2019S Lee, H Hwang, W Cho, D Jang, T Eom, DC Martin, J Wie, B Shim, Advanced Sustainable Systems, 1900134, 2020
- S Lee, B Ozlu, T Eom, DC Martin, B Shim, Biosensors and Bioelectronics, Accepted
- T Eom, J Jeon, S Lee, K Woo, J Heo, DC Martin, J Wie, B Shim, Particle & Particle Characterization Systems, 36(10), 1900166, 2019
- M Kim, B Shim, R Iezzi, DC Martin, Frontiers in Chemistry 7, 234, 2019-S Lee, T Eom, M Kim, S Yang, B Shim, ElectrochimicaActa, 313, 79-90, 2019
- S Lee, H Hwang, W Cho, D Jang, T Eom, DC Martin, J Wie, B Shim, Advanced Sustainable Systems, 1900134, 2020
- S Lee, B Ozlu, T Eom, DC Martin, B Shim, Biosensors and Bioelectronics, 170(15), 112620, 2020
- S Kang, R Baskaran, B Ozlu, E Davaa, J Kim, B Shim, S Yang, Biomedicines, 8, 417, 2020

- S Moon, J Heo, J Jeon, T Eom, D Jang, K Her, W Cho, K Woo, J Wie, B Shim, Carbohydrate Polymers, 254, 117470, 2021
- T Eom, J Lee, S Lee, DC Martin, B Shim, Submitted

USAF / DoD / Industry Relationship Highlight:

- US PI (Martin) has a short-term (9 mo.) DARPA project with K. Otto at Florida to investigate in-situ deposition of functionalized thiophenes; future plans are to conduct similar experiments on dopamine.
- US PI (Martin) is actively developing an opioid immunosensor in collaboration with Shane Kasten at U. S. Army Medical Research Institute of Chemical Defense

Programming of Graphene Properties *via* Defect Design and Characterization for Sensing: Preliminary Results (Hanyang & RX)

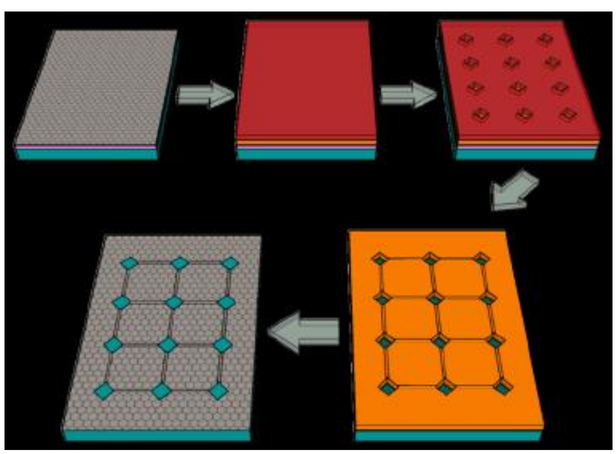
Programming the properties of graphene and transition metal dichalcogenides (TMDCs) to enable new functionalities.

Wrinkling of polymer and graphene

- Wallpapering-inspired wrinkling of thin films (accepted in Nanoscale)
- Structural analysis of graphene wrinkles (published in Appl. Surf. Sci.)
- We extend the polymer wrinkling strategy and propose a more rational route to enable wrinkling in monolayer graphene

Selective & epitaxial growth of TMDC networks on graphene wrinkles

- MOCVD setup for TMDCs growth
- Selective growth of TMDCs on graphene wrinkles
- Comparison of TMDCs on poly/single crystal graphene by Raman & PL spectroscopy

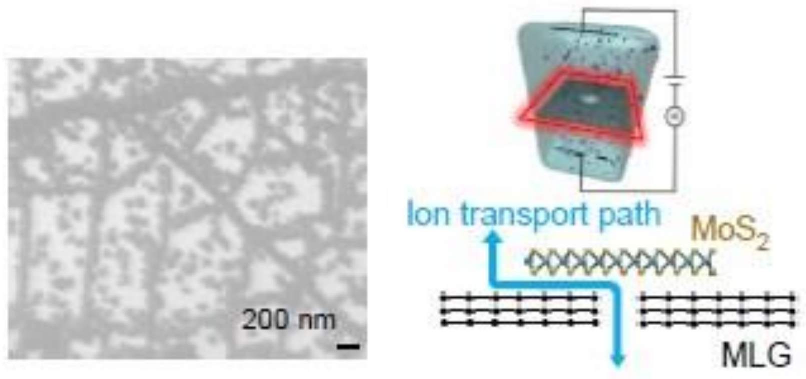


Wrinkling of graphene

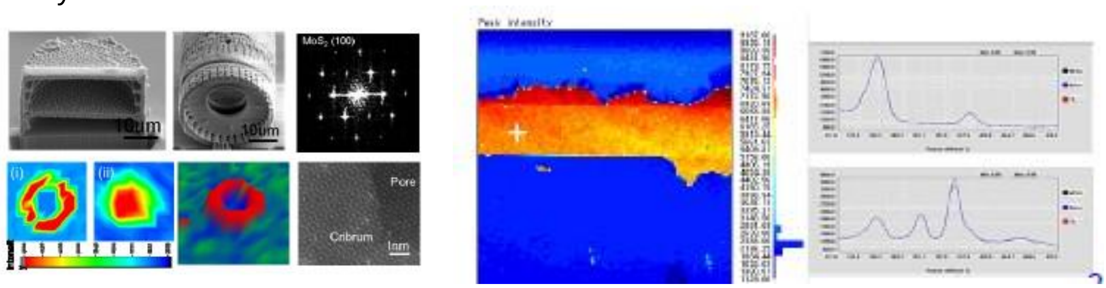
Further extend the polymer wrinkling strategy and propose a more rational route to enable wrinkling in monolayer graphene

Summary:

- MoS2 flakes (bandages) on graphene defects as a Li-ion filtering membrane



- Controlled growth and characterization of multidimensional atomically-thin TMDC layers on diatom frustules



- Direct growth of MoS2/WS2 heterostructure

USAF / DoD / Industry Relationship Highlights

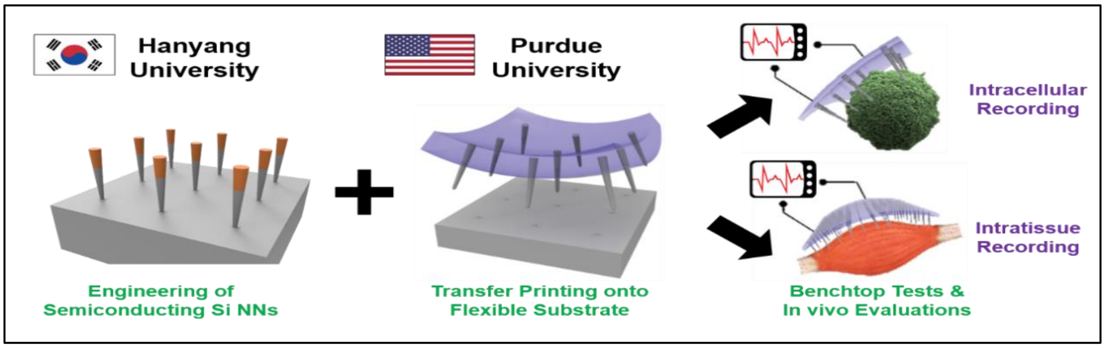
• We develop a membrane constructed by TMDC/graphene heterostructure for Li extraction from sea water and demonstrate a uniform synthesis of TMDC on 3D diatom frustules.

(Team) Collaboration Synergy Highlights (Joint papers)

• R. Pachter*, W. I. Park*, et al. “Optical response in wrinkled 2D WSe2”, in preparation
• W. J. Chang , R. Pachter*, W. I. Park*, et. al. “MoS2 bandages on graphene defects as a membrane for Li+ extraction from sea water”, in preparation.

Bio-integrated sensor patch comprising semiconducting silicon nanoneedles for intra-tissue and intracellular recording. (Hanyang & Purdue)

To integration of vertical silicon nanoneedles with flexible, bio-compatible patch for efficient intracellular access. Design realization and testing of a prototype patch with silicon nanoneedles with minimal invasiveness and high efficacies in drug delivery and electrical recording capabilities. Develop flexible, transparent and wearable nanoneedle patch.



Accomplishments & Status:

- Successfully developed a method to assemble vertically ordered silicon nanoneedles onto flexible, biocompatible elastomer patch.
- Plans to validate the utility of the nanoneedle patch in intracellular and intratissue drug delivery to evaluate therapeutic effects on skin tumor model.
- Successfully developed a novel nanoarchitecture that can be dissolvable in the body in a programmable manner and which thereby can provide clinically useful implications especially in melanoma treatment.

US Patent:

1. C. H. Lee, D. R. Kim, US 62/737,210 (Sep, 2018)
2. C. H. Lee, D. R. Kim, US 17/277,427 (Mar, 2021)
3. C. H. Lee, Y. Yeo, D. R. Kim, US 63/037,127 (Jun, 2020)
4. C. H. Lee, Y. Yeo, D. R. Kim, US 17/344,362 (Jun, 2021)

Personnel Exchange & Research Dissemination

- 5 PhD students from Hanyang University have been visiting in Purdue University since 2016 (2 visitors at any given time).
- 8 in-person annual meetings have been taking place in Purdue or Hanyang University since 2016.
- 2 joint international symposiums have been co-organized by the PIs on Dec. of 2019 and July of 2021 to bring world-leading experts in the field from universities and national labs in Singapore, Canada, and US.
- 5 presentations have been delivered in IEEE NanoMed, Materials Research Society (MRS), etc.
- 5 journal papers have been published in Nature Communications, Science Advances, and ACS Nano, along with 3 manuscripts.
- 2 intensive lectures have been delivered to Hanyang University by PI Lee (visiting professor) in winter 2020 and summer 2021.

Student/Postdoc Careers

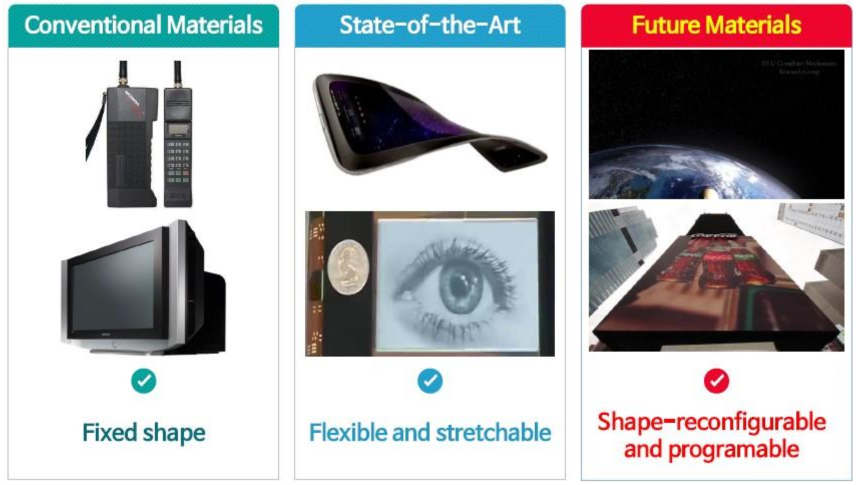
- A former PhD student in Purdue University is under review for an Assistant Professor position from Hanyang University.
- A former postdoc in Purdue University now works as an Assistant Professor at Kumoh National Institute of Technology.
- A former PhD student in Hanyang University now works at Samsung Electronics (Semiconductor) as a senior researcher.
- A former PhD student in Hanyang University now works at Korea Atomic Energy Research Institute as a senior researcher.
-

Reversibly Reconfigurable 3D Metasurface by Magnetically Programmable Polymeric Composites (MPPC) (Inha & USF)

This project aims to develop novel 3D responsive-polymer based metasurfaces to achieve low-loss, broadband and tunable electromagnetic responses.

Accomplishment:

- Developed a reconfigurable metasurface based on MPPC. The metasurface exhibits various actuation modes such as twisting, bending and assembling, which enable to control the THzamplitude and phase of MPPC-based metasurface (modulation or switch) by externally applied magnetic field.
- Developed experimental design and machine learning methods to achieve comprehensive understanding of designing parameters.
- -Programming of orientation and concentrationof magnetic particles provide various magnetic actuation modes (twisting, bending, assembly) of micropillars.
- -Anisotropic geometryisintroduced to enhance magneto-actuation of micropillars via asymmetric stress-distribution.
- Larger dimension of micropillars and silver paste coating are employed to enhance THz sensing in 0.1 –1 THz ranges.
- THz wave modulation is successfully achieved for the first time by external magnetic field.

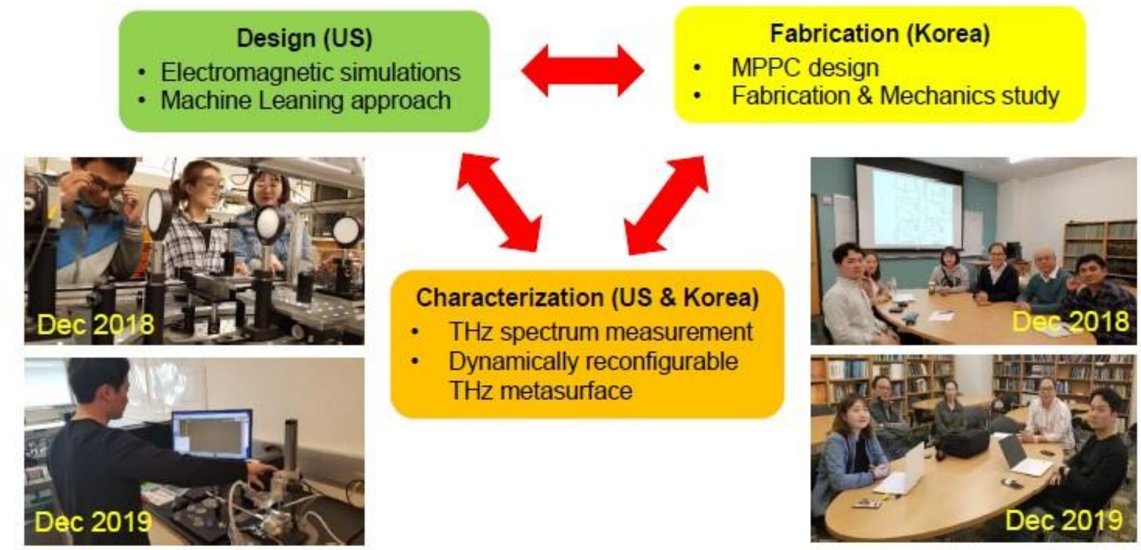


USAF / DoD / Industry Relationship Highlights.

- We are in close collaboration with researchers at AFRL to explore the opportunities for applying our metasurfaces. Our project aligns well to the interest of USAF to develop multifunctional photonic sensors.
- 10 papers/manuscripts are coauthored with AFRL researchers.

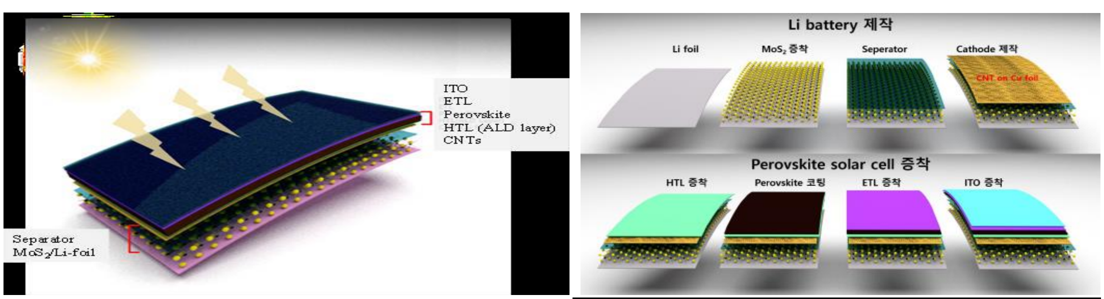
Papers & Awards:

- 20 Awards from the Materials Research Society (MRS), International Union of Pure and Applied Chemistry (IUPAC), Polymer Society of Korea (PSK), IUPAC-Micro2020, Active Materials & Soft Mechatronics (AMSM), Tokyo Chemical Society (TCI), Polymer Society of Korea (PSK), the Korean Information Display Society (KIDS), Korean Institute of Chemical Engineers (KICHE) and Inha University.
- 27 Paper publications: ACS Nano, Advanced Materials, Energy Storage Materials, Micro-Nano-manufacturing, Polymer Korea, Nature Communication, Chemical Engineering, Nano scale, and RSC Adv.
- 17 journal publications (Materials, Nano Letters, Macromol. Mater. Eng, Technometrics), 3 manuscripts in review and 2 in preparation.

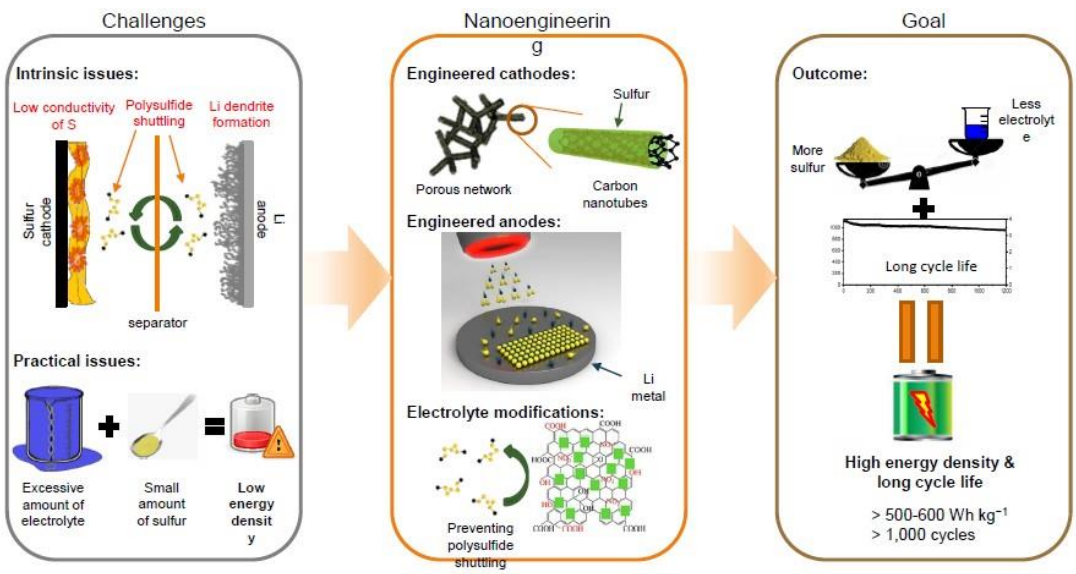


Integrated Flexible Energy System based on Two-Dimensional (2D) Materials (UNT & SKKU)

The proposed integrated, flexible, self-powered energy system with two major functionalities -high-efficiency planar perovskite solar energy conversion (> 20% efficiency) and 2D Li-S rechargeable battery (> 500 Wh/kg and 1,000 cycles)



To develop a novel integrated, flexible, self-powered energy system with two major functionalities - high-efficiency planar perovskite solar energy conversion and high density Li-S rechargeable energy storage**.** Very high energy storage efficiency of the self-powered energy system and provide extremely effective space utilization (compactness) and very high energy density (per weight). Improvement in overall Size, Weight, and Performance (SWAP)



Accomplishment:

Project characterized unusually high ionic conductivity on 2D MoS2nanofilm exceeding 1 S/cm, which is more than two orders of magnitude higher than the state-of-the-art solid ionic materials. Developed electrocatalysts coated 3D CNF cathode and hybrid electrolyte resulting in high energy density Li-S battery (>500Wh/kg).

Patents/Papers

Produced two (2) patents and seven (7) papers including two under review.
The patents have been licensed to a start-up company to perform development of the technology for practical application.

Follow-on awards enabled by NBIT/AOARD support

DOD-DURIP grant has been awarded, and the in-situ Raman study for 2D ion channel and perovskite solar cell will be performed.

Summary of the MSIT-AFOSR Korea Programmable Materials and Next Generation Nanosystems.

US-Korea Nanotechnology Initiative program has completed with very successful outcome and results. Each project was recognized and awarded their research achievements and some are in the plan to transition into the commercial world. Tremendous accomplishments in the form of journal papers, patents, and presentations of their findings as follow:

6 Patents, 54 Papers, 17 Journals, 20 Awards
1 DoD DURIP Project Awarded
1 DoD DURIP Project in process.

Program Manager (PM): Dr. Tony Kim, AOARD

Tying it back to the Lab

A key pillar of the AF 2030 strategy is: "The Air Force will expand and deepen access to scientific and technical talent through internal workforce enhancement and stronger partnerships across the national and international enterprise." This is further emphasized in objective 3: "Air Force technological superiority has always relied on a national and international enterprise, including government laboratories and a synergistic network of universities, industry, and allies. As allies and adversaries become more technologically capable, these relationships will become even more important." In the spirit of AF 2030 guidance, a new operating instruction (OI) is being developed to define and reaffirm the international initiative model.

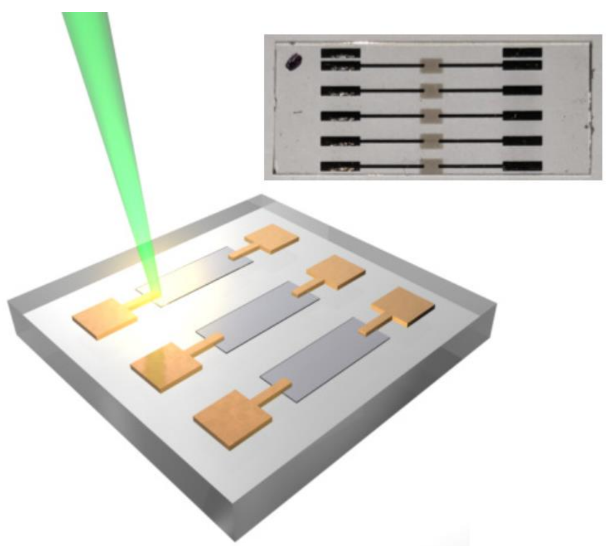
Many XOARD international program managers are detailees from a technical directorate (TD). It's hard to envision being any more tied to the lab than that! A pilot study has been conducted to include TD researchers as partners in AFOSR/IO's international initiative programs with Taiwan, South Korea, and now Singapore. Moving forward, teams of 3 are envisioned to include a TD PI, international university PI, and a US university PI. See Singapore section for the first example of this.

TD participation in international initiative program from FY15 to present

Title	Location	Country	Principal Investigator
Graphene Infrared Transparent Electrode (GITE) and Thermal Enhancer for the Hybrid Energy Nanodevice	Air Force Research Lab National Dong Hwa Univ	US Taiwan	Mou, Shin Ma, Yuan-Ron
High-Conductivity and High-Mobility Doped AlGaN for Electronics and Optoelectronics Applications	AFRL/RXAP National Taiwan Univ	US Taiwan	Averett, Kent Yang Chih-Chung
Development of Biocompatible X-ray Scintillating Nanoparticles for Biomedical Applications	AFRL/RXAN Academia Sinica	US Taiwan	Boeckl, John Hwu Yeu-Kuang
Mechanically robust and photo-reconfigurable epoxy nanocomposite by dynamic covalent reaction	AFRL/RXCC Hanyang, Univ	US South Korea	Nepal, Dhriti Kang, Young Jong
Programming for graphene properties via defect design and characterization	AFRL/RX Hanyang Univ	US South Korea	Pachter, Ruth Park, Won Il
Exploring and Exploiting Transient Phase Diagrams in Electronic Materials	AFRL/RXAS National Taiwan Univ	US Taiwan	Glavin, Nicholas Hofmann, Mario
Layered Topological and Functional Materials: Single Crystal Synthesis, Characterizations, and Applications	AFRL/RXAP National Cheng Kung Univ	US Taiwan	Susner, Michael Lue, Chin-Shan

An example highlight of a FY21 new start with Dr. Nicholas Glavin from AFRL/RX and Prof. Mario Hofmann from National Taiwan University seeks to massively accelerate the design of sensor materials.

Program Officers at AFOSR/AOARD, researchers in AFRL/RX, AFRL/RH, and academic partners in the US and Taiwan are developing a strategy to significantly accelerate the design of chemical sensors built around 2D materials. While these materials have demonstrated unprecedented sensitivity in detecting chemical and biological threats relative to many commercial materials, they are many times limited to a handful of devices as fabrication can be challenging. AFRL pioneered a laser processing method to convert amorphous molybdenum disulfide (MoS2) to the subsequent crystalline phase, which rapidly generated over 5500 unique and distinct conditions on single chip. The generation of structural/property relationships from this massive series of parameters enabled the data-driven design of chemical sensors, where the device performance was shown to be strongly dependent upon thickness and grain orientation and less dependent upon expected parameters including defects, crystal size, strain, and doping.



For more details: https://arxiv.org/abs/2201.11289

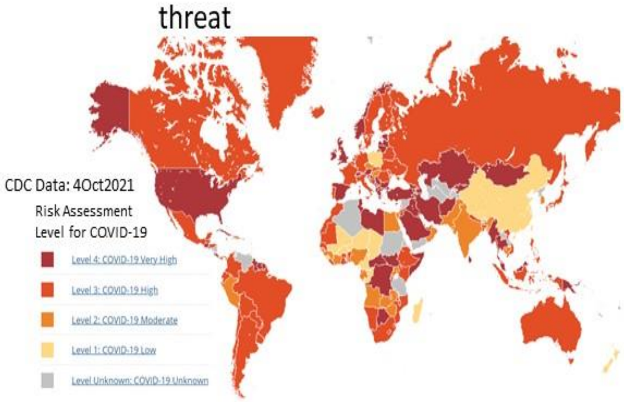
WOS: Widows on Science Program

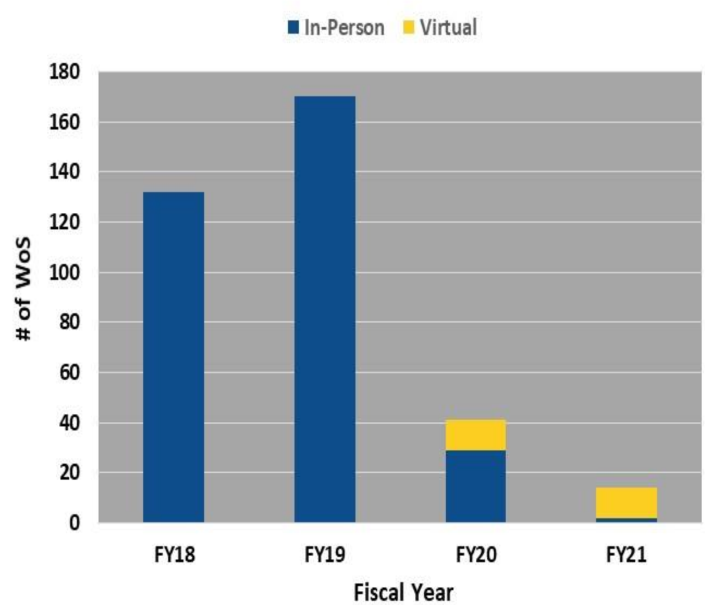
The Window on Science (WOS) program facilitates technical interactions on fundamental research via direct contact between distinguished foreign researchers and Air Force Research Laboratory scientists and engineers. The WOS program sponsors foreign scientists and engineers to visit Air Force and Space Force scientists and engineers at DAF sites typically within the U.S., but may also include other domestic or overseas locations. The WOS visits are designed to be short-term in nature and is not intended as a substitute for research programs, internships, associateships, or personnel exchange programs.

Program Officer: Ms. Joanne Maurice

FY21 Windows on Science (WoS) Data

- 14 WoS convened
  - 12 *"Virtual WoS"* meetings
  - AFRL/RV hosted 2 WoS visitors
- COVID-19 continues to impact WoS travel
  - 35 cancellations
  - Delta variant added a new level of threat





"Windows On Science (WOS)" and "Window On World (WOW)" Programs Overview

The "Windows On Science (WOS)" and "Window On World (WOW)" Programs provide travel support for technical interchange and resident researcher opportunities, respectively. Under WOS, foreign researchers visit DAF Scientist and Engineer (S&E) hosts over short-terms, a few days to a week, with the perk of Base access for traveler and host facilitated as a courtesy. Under WOW, DAF S&Es access unique facilities fulltime, *in situ,* as resident researchers at OCONUS host institutes for longer terms and work alongside prominent researchers.

FY21 – Again the global pandemic affected plans in a big way. In a year like no other, not a project within either the WOS or WOW programs would be without incident. Postponements and reschedules from FY20 would see more of the same. Yet unlike FY20, FY21 would be nearly entirely eclipsed. Hopes would be met by setbacks. Efforts would end in frowns with a chorus of groans. "Do, redo, undo; repeat," all but two in-person WOS visits would be cancelled; in WOW, all projects put on-hold in a queue.

A WOS program setback came with the January 2021 declaration of a new policy restricting entry to the United States. While the need was not too surprising, the "Schengen Travel restriction" would apply to foreign researchers from nearly every nation AFOSR/IO works with most scheduled WOS visits. Called the "National Interest Exemption (NIE)," it meant additional State Department vetting beyond typical Visa or ESTA waiver processes and would add months' more waiting on approval for entry. Set to expire at the end of July, WOS planners acted accordingly to send WOS PIs, often professors, to waiting S&E hosts before resumption of the academic year. The WOS team provided PIs an advantage on applying for their NIEs: Simple recapture of boilerplate agreement language, as featured already to parties involved in WOS coordination (host, traveler, IPO, Foreign Disclosure Office, etc.), would work well with Embassies granting NIE approval. Then came the COVID Delta variant! The NIE restriction, set to expire in July, would not lift till November and since has left long in-country backlogs at Embassies. Meanwhile, with variant spread threatening the academic year worldwide, many institutes would impose their own respective restrictions on members. The sum of these factors would foil the purposeful planning of most WOS visits for FY21. Face-to-face WOS visits were few; far more went "virtual." For visits convening on virtual platforms, participating PIs would present, panel and/or lead sessions, and be active in "chat." Dozens were noted. For annual research reviews of AFOSR program officers, WOS PIs would populate the attendance lists. In the TDs too, as in by-invite virtual reviews and update meetings, names of PIs whose visits had been fully coordinated and authorized at time of cancellation were noted.

WOS visits from most recent years (FYs 18-20) would continue to enhance efforts underway. For example: (i) in AFRL RX for RW, the THEOR3M program with Israel's Technion and Spain's University of Madrid, also linking with a TTCP/DST-G topic to optimize the response of emerging extreme-environments materials, (ii) in AFRL/RQ, synthetic biology for defense topics include microbial contamination and biodegradation in the PA "Fuel Contamination Protective Technologies" between AFRL and Singapore and joint work on microbiome influences on cognitive and physical performance for the 711th HPW, (iii) microstructure measurements at the University of South Adelaide's specialized gas gun facility characterized multiphase steels for armaments in AFRL/RX and, in turn, AFRL/RW, (iv) an IEA, PA, and CRADA with Canada are accelerating work on quantum communication networks and come stepwise with inhouse cold ion trapping testbed experimentation developed over WOS visits at AFRL/RI, particularly an extended one, (v) as well as subsequent awards in the Israel, Korea, and Taiwan Initiatives reported in this Report and elsewhere.

Two WOS visits would go forth in-person, happening face-to-face for a full week each, providing short course coverage of cutting-edge techniques – both, opportune intercepts of accomplished German researchers be hosted by working groups at USSF and AFRL/RV. Highlighted below, a few projects just glossed over illustrate how WOS is unparalleled as an easy, cost-effective means to inform stakeholders while strengthening connections between basic and applied research.

For more information on the WOS and WOW Programs, please contact Ms. Joanne Maurice

WOS SUCCESS STORIES

23-27 August 2021: AFRL/RV and USSF host WOS PI Dr. Roland Wester, Institute of Ion Physics and Applied Physics, University of Innsbruck, Austria; 28 September - 2 October 2021: AFRL/RV and USSF Albuquerque host WOS PI Dr. Gereon Niedner-Schatteburg.

In need of unanticipated travel assistance on trips (thought) fully arranged, two separate opportunities arose for pop-up visits of outstanding WOS PI talents to visit with USSF and AFRL/RV. First was a flight change and delay for Professor Roland Wester in August, enroute to a teaching sabbatical at U C Berkeley, possibly with a Visa conflict. Second was Dr. Gereon Niedner-Schatteburg, who required assistance to not only access Kirtland AFB after unrelated university travel but to enter the USA in the first place – surprise! As with other intended WOS visits this year, the requirement of an approved, in-place National Interest Exception (NIE) for entry to the US was unexpected. For most WOS PIs, the new “step one” became coordination of an NIE through local embassies of the State Department, additional to Visa or ESTA waiver processing. Only then could the usual next step proceed, which is coordination with local Foreign Disclosure Offices at DAF Bases. NIE lead times varied country to country, embassy to embassy, with different web sites and instruction sets depending on passport details.

Successfully navigating the maze, both talents were intercepted diverted to research groups at AFRL/RV under Dr. Al Viggiano, USSF. Prof. Wester did a detour – roundtrip between Denver and Albuquerque; Prof. Niedner-Schatteburg, a teaching gig in the Lab on his quantum chemistry models. Introductions are in order.

First is Prof. Wester, Faculty Dean of Mathematics, Computer Science and Physics, University of Innsbruck, as well as molecular physicist and quantum chemist: Recently transitioned from University of Freiburg, Germany, and now appointed full professor at Innsbruck, Austria, he is recognized with EU top awards. He is identified as an EU most promising young researcher. The versatile spectroscopy tool he pioneered won him the European Research Council’s highest distinction for advanced science, a 2.5 million euro grant for five years. The tool uses radio-frequency-trapped cryogenic multipole ions to probe complex molecular dynamics, literally brings chemical reactions into focus! Applications range from astrophysics to organic and biochemistry. Second is Prof. Niedner-Schatteburg, currently Physicist and Chemist at the University of Kaiserslaughtern, Germany: A trans-regional scholar, he has belonged to most every prestigious institute in the EU and several in the US. A master of many tricks and techniques in cold science spectroscopy and quantum chemistry, Wikipedia pages are devoted to him and outline a storied career. Prof. Niedner-Schatteburg's current research has turned to reaction kinetics and spectroscopy of transition metal clusters and complexes held in isolation. He made it into the US and onto Base, as schedule, staying an additional week with his Albuquerque hosts. The tutorial he presented on modeling of molecular clusters and select spectroscopic studies shared provide insight to ion-molecule interactions and reactivity for AFRL and USSF S&T. For more information, please contact Ms. Joanne Maurice

[Virtual WOS, PI Rizzo to USSF SoPC, HQ, 2-4 June 2021 Space Futures Workshop / Summit]

USSF SpOC hosts WOS PI, Professor Gabriele Rizzo, University of Lausanne, Switzerland, and Sapienza University, Rome, Italy.

Additional travel restrictions related to the global pandemic meant cancellation of in-place WOS arrangements for PI Gabriele Rizzo to join onsite June's second in its series "Space Futures Summit," convened at USSF SpOC Headquarters, Colorado Springs. Prof. Rizzo, teaches at the University of Lausanne in Switzerland and Sapienza University in Rome, his home, where he has also served as Lead Scientist at Leonardo, Italy's industrial aerospace corporation. He participated in-person at the first Summit, 2019, and transatlantic via secured virtual option on this second when both in-person and virtual options were offered intended participants. Prof. Rizzo is a consultant to the NATO Science & Technology Organization and advisor to NATO strategic commands. Above all else, he is an enthusiastic futurist! A familiar interface to this professional community of US DOD top specialists in military space applications, he facilitated and stimulated strategic thinking. Although remote this time, again he led the panel – a mix of members in-person and virtual – in a process which laid out a realistic range of "probable futures," sets of space scenarios, technologies, attributes, etc. Future concepts first defined and then explored. Outcomes enhance an understanding of S&T challenges and impediments shaping those futures. The analysis helps drive space concept development, transition current concepts, and prioritize vectors and the Force structure to meet foreseen missions.

For more information on Prof. Rizzo and his contributions, please contact Ms. Joanne Maurice

ISEP: International Student Exchange Program

The International Student Exchange Program (ISEP) is an opportunity for the AFOSR Program Officers to give a currently funded Principal Investigator's (PI) graduate student the opportunity to work with a currently funded overseas collaborator for a short term, or the opportunity for an overseas collaborator to send their graduate student to work with the currently funded AFOSR PI in U.S. for a short term (~10 weeks). The ISEP program is to enhance the existing grant by collaboration and access to unique equipment, sharing/learning new techniques, joint authorships, which could further enable significant advances towards Air Force and Space Force Science & Technology (AF S&T) objectives. This program intend to develop a long lasting friendship/collaboration that could lead or enable significant advances towards science and help identify advances in emerging opportunities within the international scientific community. This program could also further assist AFOSR leadership a means to evaluate highly promising new international research, and direct additional funding towards areas of strategic Air Force and Space Force mission.

ISEP List

Student	Principal Investigator	Research Title	PI Institution	Hosting Institution
Guy Wilner	Guillermo Paniagua	Embedded Flow Control for High Work /Low Reynolds Turbines – BFCONTUR	Technion - Israel Institute of Technology	Purdue University
Jacob Neal (RPI), Jean Ribeiro (UCLA), Daniel Flanagan and Kamil Dylewicz (Liverpool)	Michael Amitay, Vassilis Theofilis, Kunihiko Taira	Flow Physics and Control of 3-D Separation on Finite Span, Tapered and Swept Wings	U of Liverpool (2 students) UCLA RPI	UCLA U of Liverpool U of Liverpool
Vedasri Godaverthi (UCLA), Jarred Callaham (U Washington)	Kunihiko Taira (UCLA, PI), Steven Brunton (U Washington, co-PI)	Data-Driven Control of Unsteady Flows	UCLA & U of Washington	TBD
PI - TBD	Nicholas Bedford	Molecular Alignment at Functional Biotic/Abiotic Interfaces for Biosensing	U of New South Wales	711HPW/RH & Lawrence-Berkley National Lab
Madeleine DeBrosse	Saber Hussain Jason Heikenfeld	Operationally Relevant Molecular Biosignature Discovery and Evaluation for Sensing Platforms.	U of Cincinnati	ZHAW School of Engineering, Winterthur, Switzerland
Paul Conway	Tomás Ryan	Innate Memory – the Plasticity of Instinct	Trinity College Dublin	Harvard University

Emanuela Saracino	Saber Hussain	Investigation of biophotonic cellular communication to understand mechanisms of performance	Istituto per la Sintesi Organica e la Fotoreattività, Bologna, Italy	Wright State U
Juliane Pawlitzki	Thorsten O. Zander	UNILOAD	Brandenburg University of Technology	711 HPW/RHBCN
Juliane Uhlhorn	Gregor Belusic & Mathias F. Wernet	Multi-leveled Matched Filters Underlying P0larization Vision in Flies, Butterflies, and Moths	Freie Universität Berlin	Columbia University & Janelia Research Campus (Ashburn, VA)
Rodrigo Tavares Veloso	Pedro Paredes Gonzalez	Novel Concepts for Transition Delay in Hypersonic Boundary Layers and their Optimization	Universidade Federal Fluminense (UFF), Brazil	National Institute of Aerospace (NIA), Hampton, VA
Andrew Hartmann	Hermann Fasel	Numerical Investigation of Nonlinear Transition Stages in Hypersonic Boundary Layers for Wind-Tunnel and Free-Flight Conditions	University of Arizona	University of Stuttgart
Gregory Stroot	Beverley McKeon	Resolvent analysis of coherent structures in turbulent flows	California Institute of Technology	Imperial College London
Haira Hackbarth	Nicholas Bedford	Understanding Atomic-Scale Structure of Preceramic Polymers, Intermediate Phases, and Final Ceramics.	U of New South Wales	RX, Wright State U & Argonne National Laboratory, IL
Olivia J. Morley	Dana D. Dlott	Shock initiation of energetic material microstructures	Cambridge U	U of Illinois
Shobhan Roy	H. S. Udaykumar	Integrating Multiscale Modeling and Experiments to Develop a Meso-Informed Predictive Capability for Explosives Safety and Performance	U of Iowa	Oxford U
Emmanuel Johnson	Jonathan Gratch	Organizational Implications of Auton-omy-Mediated Interaction	USC	African Methodist Episcopal University (AMEU) & Harbel College, Liberia
Ching-Chung Chen	Yu-Ru Lin	Linking Online Attention to Measurable Actions	National Sun Yat-sen University, Taiwan	U of Pittsburgh

CONFERENCES & WORKSHOPS

Title: SOARD Builds Research Community to Benefit DoD Energetic Materials Research

AFOSR Southern Office of Aerospace Research & Development (SOARD) co-hosted the 2021 Interfaces and Effects in Composite Energetic Materials (IECEM 2021) Conference on 13-15 April 2021, along with AFRL's Munitions Directorate and the ARL's Weapons and Materials Research Directorate. This is the only conference bringing together scientists and engineers (experimentalists and computationalists) from across the DoD, DOE, academia, industry, and foreign government partners to discuss the basic research challenges in characterization, modeling, and properties related to interfaces in energetic materials. Non-traditional partners (pharmacy, cosmetics) brought a long history of research, and wealth of insight into the interfacial problem, benefitting DoD researchers just beginning to understand the importance of interfacial phenomena in bulk material research. Four subcommittees were created (Characterization, Material properties, Modeling and simulation, and Additive manufacturing) which will address (i) Formation of relevant publication standards for each sub-community and publish recommendations in relevant peer reviewed journal, (ii) Identify a model system or material to include in studies and publications for standardization and comparability, and (iii) Parameters of interest for reference database. Beginning in 2022, this conference will be held at the Materials Research Society's annual International Materials Research Congress (IMRC) under the umbrella of the Advanced Defense Materials subcommittee.

Title: STEM Outreach with Underserved Students in Santiago, Chile

The COVID-19 pandemic forced us into a time of physical distance and virtual learning. Educators and STEM advocates had to think about creative ways to engage their classrooms and continue to advance scientific literacy. The Air Force Office of Scientific Research, the National Human Genome Research Institute and the Department of State collaboratively created educational programming to support students in a virtual environment and connected with classrooms around the world. This program recruits participants from under-resourced schools and provides them with hands-on learning opportunities and critical-thinking exercises. Students are asked to "think like a scientist" and create a project proposal to present to a classroom from another country. This illustrates the global impact that science can have and the unique cultural perspectives that can inspire our research. For the students in San Bernardo, Chile the program was their first experience meeting a scientist. Dr. Stacy Manni connected with and mentored students sharing opportunities that they could pursue e.g. four-year degrees, STEM summer camps, etc. In the United States, Ms. Rosann Wise was able to supplement and enhance the career and technical education program with mentors, educational resources and activities.

Image of participants from the kick-off meeting in the comuna of San Bernardo in the Metropolitan Region of Santiago, Chile.

AWARDS - SPECIAL RECOGNITION

Title: COVID-19 research affecting Chilean Vaccination and Booster Policy

On 24 June 2021, Dr. Tomas Perez-Alce and his team delivered a report to Dr. Enrique Paris, Chilean Minister of Health, stating their analyses suggested fully vaccinated people over 60 were experiencing a dramatic reduction of the protection against COVID-19 provided by the vaccines. They urged the minister to start booster inoculations as soon as possible, mainly due to the imminent arrival of the Delta variant to Chile. Dr. Perez-Alce published the report through his tweeter account on Sunday, 27 Jun 2021. This report and tweet produced more than 334,000 views, giving rise to a massive discussion over social media. Through these discussions, they convinced Dr. Enrique Paris of the need for the required booster shots. Dr. Paris then convinced Chilean President Piñera to issue the booster decree on Monday, June. The government has applied a massive set of booster doses to the population from that date and on. By mid-December 2021, more than 78% of the Chilean population had had active protection against COVID-19 provided by the vaccines. The mild impact of the Delta variant in Chile compared to other countries in Europe, and the US can only be explained by the active protection provided by the booster jab. Through the continued support of AFOSR and AFRL/RI, Dr. Thomas Perez-Alce and his team have been able to affect public policy for the good of Chile and the world.

Appendix: List of Grants

Country	Institution	Principal Investigator	Project Title
Argentina	UNIVERSIDAD NACIONAL DE SAN MARTIN	Rubio, Aurora	Non-destructive interrogation for composite materials
Argentina	UNIVERSIDAD NACIONAL DE LA PLATA	Idiart, Martin	Imperfect interfaces on the hereditary thermomechanics of microstructures
Argentina	FUNDACION CIENCIAS EXACTAS Y NATURALES	FERRER, LUCIANA	Detecting Distrust Towards a Virtual Assistant from the User's Speech
Australia	THE UNIVERSITY OF QUEENSLAND	McIntyre, Timothy	Study of non-equilibrium wakes model
Australia	MACQUARIE UNIVERSITY	Heimlich, Michael	GaN Modeling & CAD
Australia	THE UNIVERSITY OF QUEENSLAND	Stace, Tom	Cluster-State Quantum Error-Correction Based on AdS/CFT
Australia	MACQUARIE UNIVERSITY	Jackson, Stuart	Fluoride glass transmission for 4 micron fiber laser systems
Australia	AUSTRALIAN NATIONAL UNIVERSITY	Williams, Jim	Mid-Infrared Photodetectors
Australia	COMMONWEALTH SCIENTIFIC AND INUSTRIAL RESEARCH ORGANISATION	Chen, Fang	A Longitudinal Study of Trust Calibration Methods with Individual Differences
Australia	MACQUARIE UNIVERSITY	Mildren, Richard	Exploitation of anomalously fast heat dissipation in diamond
Australia	WESTERN SYDNEY UNIVERSITY	Cohen, Gregory	Event-Based Cameras and their Potential Applications to Space Situational Awareness
Australia	THE UNIVERSITY OF QUEENSLAND	Veeraragavan, Anand	Examining Growth of Turbulence over Heated Walls in Hypersonic Flows
Australia	University of New South Wales	Galliott, Jai	The warfighters tolerance for autonomy strategy and systems
Australia	WESTERN SYDNEY UNIVERSITY	Cohen, Gregory	Exploring the use of Event Based Imaging Sensors on Turbulence Characterisation and Adaptive Optics
Australia	COMMONWEALTH SCIENTIFIC AND INUSTRIAL RESEARCH ORGANISATION	Heiser, Gernot	Provable Time Protection for Eliminating Timing Channels

Australia	DEAKIN UNIVERSITY	Henderson, Luke	Using electrochemically initiated radical polymerization to develop novel sizing
Australia	University of New South Wales	Gai, Sudhir	Wall Temperature and Bluntness Effects
Australia	University of New South Wales	Neely, Andrew	Unit Cases to Investigate Hypersonic Fluid-Structure Interaction
Australia	MONASH UNIVERSITY	Le, Trung	Deep Generative Models for Learning from Multiple High-Dimensional Data Sources
Australia	QUEENSLAND UNIVERSITY OF TECHNOLOGY	Ralph, Timothy	Enabling quantum information technology with 60 photons and beyond
Australia	CURTIN UNIVERSITY OF TECHNOLOGY	Bray, Igor	Quantum collision theory for photon scattering from atoms and molecules
Australia	MACQUARIE UNIVERSITY	Fuerbach, Alex	All Integrated Ultrafast Mid-Infrared Fiber Lasers
Australia	University of New South Wales	Ravi, Sridhar	Bio-Inspired Compliant Musculoskeletal Actuation for Miniature Robots
Australia	UNIVERSITY OF SYDNEY	de Sterke, Martijn	The Pure-Quartic Soliton Laser
Australia	UNIVERSITY OF SYDNEY	Dunn, Matthew	Mixed-Mode Flames from Highly Turbulent Premixed to Diffusion
Australia	UNIVERSITY OF SYDNEY	Manchester, Ian	Multi-UAV Monitoring and Intervention
Australia	THE UNIVERSITY OF QUEENSLAND	Horvath, Ildiko	Electromagnetic Energy
Australia	ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY	Mohamed, Abdulghani	Unsteady aero-structural response of natural flyers in turbulent environments
Australia	SWINBURNE UNIVERSITY OF TECHNOLOGY	McArthur, Sally	Development of 3D cell culture systems for evaluating real-time stimulation
Australia	FLINDERS UNIV OF SOUTH AUSTRALIA SALISBURY	Nordstrom, Karin	Target tracking in the natural world: From neurons and behavior to modellin
Australia	THE UNIVERSITY OF ADELAIDE	Ebendorff-Heidepriem, Heike	Nano-micro-particle and RE doped glasses for mid-IR fiber lasers and microlasers
Australia	DEAKIN UNIVERSITY	Aryal, Sunil	Robust Data Mining
Australia	QUEENSLAND UNIVERSITY OF TECHNOLOGY	Stace, Tom	Introducing the superconducting Saddle-Point qubit

Australia	UNIVERSITY OF SOUTHERN QUEENSLAND	Schubel, Peter	Self-learning Process Modelling in Composites Manufacturing
Australia	UNIVERSITY OF TECHNOLOGY SYDNEY	Aharonovich, Igor	Interlayer Excitons as quantum emitters in 2D materials
Australia	ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY	Menicucci, Nicolas	Quantum illumination with multi-mode Gaussian resource states
Australia	MACQUARIE UNIVERSITY	Terno, Daniel	Relativistic quantum metrology: polarization effects
Australia	THE UNIVERSITY OF QUEENSLAND	Veeraragavan, Anand	Heated Wall Supersonic Combustion Testing of Hydrocarbons
Australia	THE UNIVERSITY OF ADELAIDE	Perrella, Chris	Demonstration of a Two-Photon Atomic Clock with Light Shift Suppression
Australia	University of New South Wales	Brown, Melrose	Machine Learning SSA Frameworks for Photometric Light Curves
Australia	THE UNIVERSITY OF ADELAIDE	Luiten, Andre	BreathELISA: Breath analysis for detection of disease
Australia	University of New South Wales	Bedford, Nicholas	Atomic-Scale Structure of Preceramic Polymers to Final Ceramic
Australia	THE UNIVERSITY OF QUEENSLAND	Veeraragavan, Anand	Advanced Ground Testing and Simulation of the BOLT Flight Experiment
Australia	University of New South Wales	Aziz, Haris	Efficient and Fair Decentralized Task Allocation Algorithms
Australia	Australian National University	Xie, Lexing	Linking Online Engagement to Pandemic Responses
Australia	UNIVERSITY OF NEW SOUTH WALES	Mao, Guangzhao	Charge-transfer Complex Nanowire Electrochemistry
Australia	University of New South Wales	Ravi, Sridhar	The effects of freestream and kinematic perturbations on oscillating wings
Australia	QUEENSLAND UNIVERSITY OF TECHNOLOGY	FEDOROV, ARKADY	Clean and Tunable Phase Slip Qubit
Australia	THE UNIVERSITY OF ADELAIDE	Ebendorff-Heidepriem, Heike	Chaos in fiber lasers and amplifiers: breaking through nonlinear and therma
Australia	ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY	GREENTREE, ANDREW	Quantum Correlation Microscopy: progressing nanoscopy
Australia	THE UNIVERSITY OF QUEENSLAND	BOWEN, Warwick	Quantum control of biomolecular vibrations
Australia	UNIVERSITY OF NEW SOUTH WALES	Bedford, Nicholas	Molecular Alignment at Functional Biotic/Abiotic Interfaces for Biosensing

Australia	UNIVERSITY OF MELBOURNE	CHUNG, DANIEL	Advancing the flow physics behind the drag of riblets
Australia	DEAKIN UNIVERSITY	HODGSON, PETER	SPD powder route for HEA alloy production
Australia	UNIVERSITY OF SYDNEY	RABEAU, JAMES	Acceleration measurements with a diamond quantum sensor
Australia	MACQUARIE UNIVERSITY	MILDREN, RICHARD	High power visible and UV diamond Raman lasers for adv mesospheric beacons
Australia	UNIVERSITY OF NEW SOUTH WALES	POOLE, KATE	Do mechanically activated ion channels enable cellular sensing of microgravity?
Australia	MONASH UNIVERSITY	JONES, CAMERON	Highly Activated Low-Valent Main Compounds for Selective Transformation of Inert Molecular Substrate
Australia	UNIVERSITY OF NEW SOUTH WALES	RAVI, SRIDHAR	The Navigational Toolkit in Insects and Bio-inspired Strategies for Aerial Robots
Austria	UNIVERSITT WIEN	Walther, Philip	Photonic Quantum Computing via Graphene Nanostructures -- PhoQuGraph
Austria	LEOPLD FRNZENS UNIVERSITT INNSBRUCK	Blatt, Rainer	Creation and control of large-scale entangled quantum matter
Austria	LEOPOLD FRANZENS UNIVERSITAT INNSBRUCK	WOODS, DANIEL	Measuring Return on Attack: Combining Exploit Market Data with Attack Trees
Austria	UNIVERSITY WIEN	WALTHER, PHILIP	Quantum Resources for Enhancing Network Trust (Q-TRUST)
Belgium	INSTITUT VON KARMAN DE DYNAMIQUE DES FLUIDES VZW	Magin, Thierry EB	Nonequilibrium Gas-Surface Interactions at High Temperature
Belgium	KATHOLIEKE UNIVERSITEIT TE LEUVEN INST. OPENB. NUT	Poedts, Stefaan	Towards a novel multi-fluid coronal model
Belgium	UNIVERSITEIT GENT VZW	Shawkey, Matthew	Biomimetic optical nanostructures from melanin and melanin composites
Belgium	INSTITUT VON KARMAN DE DYNAMIQUE DES FLUIDES VZW	Chazot, Olivier	Investigation of thermal non-equilibrium effects in rapid flow expansions
Belgium	Vrije Universiteit Brussel	DEVRIESE, DOMINIQUE	From Secure Compilation to Secure Abstractions: Stronger Foundations
Belgium	UNIVERSITEIT GENT	BOGAERTS, WIM	Exploring Photonic Band Structures, Topologies and Photonic Molecules

Brazil	FUNCATE - FUNDACACAO DE CIENCIAS	Rossi, Jose	HV Dielectrics for High Freq Operation & Hybrid Nonlinear Lines for RF Gen
Brazil	UNIVERSITY FEDERAL FLUMINENSE	Alves, Leonardo	Instability Free Three-Dimensional Hypersonic Laminar Boundary Layer Steady
Brazil	Fundacao de Apoio a Universidade de Sao Paulo	Faraco de Medeiros, Marcello	Surface Irregularity Effects on Laminar-Turbulent Transition
Brazil	FACULDADES CATOLICAS	Milidiú, Ruy	Ad Hoc Teams With Humans And Robots
Brazil	FACULDADES CATOLICAS	Costa, Emanoel	Analysis of the Effects from Equatorial Plasma Bubbles Detected by the C/NO
Brazil	Universidade Estadual de Campinas	de Assis, Pierre-Louis	2D heterostructures for integrated on-demand single-photon sources
Brazil	UNIVERSITY FEDERAL FLUMINENSE	de oliveira, thiago	Foundations of Statistical Mechanics and Quantum Correlations
Brazil	INSTITUTO DE FISICA DE SAO CARLOS	Marcassa, Luis	Laser-slowing and trapping of molecules for ultracold chemistry
Brazil	Fundaçao de Desenvolvimento da Unicamp Funcamp	Sollero, Paulo	Multiscale modeling of additive manufacturing of fiber-reinforced composite
Brazil	UNIVERSITY FEDERAL FLUMINENSE	Alves, Leonardo	Absolute Instability of Interacting Planar Mixing Layers and Wakes
Brazil	FUNDACAO DE APOIO DA UNIVERSIDADE FEDERAL DO RGS.	Da Cunha, Carlo	Probing the Quantum-Classical Transition with Bayes-Enhanced Scanning Gate
Brazil	Fundacao de Apoio ao Desenvolvimento da UFPE	Gomes, Anderson	Experimental investigation of the nonlinear properties of NbX2 Hybrid LTMDs
Brazil	FACULDADES CATOLICAS	Endler, Markus	Flight Coordination of Fleets of UAVs for WSAN and WMesh
Brazil	UNIVERSIDADE ESTADUAL DE CAMPINAS .	PADILHA, LAZARO	Multidimensional Coherent Spectroscopy Revealing Hidden Properties of Nanomaterials
Brazil	UNIVERSIDADE FEDERAL DE JATAI	PANCOTTI, ALEXANDRE	Surface structure and electrical characteristics of epitaxially grown Ga2O3
Bulgaria	INSTITUTE OF ASTRONOMY & NATION ASTRONOMICAL OBSERVATORY	Kozarev, Kamen	Remote Sensing of Coronal Mass Ejections using Widefield Low Freq Imaging Arrays

Bulgaria	NEW BULGARIAN UNIVERSITY	Apostolova, TZVETA	Simulation of Radio Frequency Radiation Generation from Ultraintense Lasers
Cambodia	INSTITUTE OF TECHNOLOGY OF CAMBODIA	SRANG, SAROT	Study on Control of Unmanned Aerial Vehicle with Solar Tracker
Canada	UNIVERSITY OF WATERLOO	Morris, Kirsten	Optimal Sensor Location for Distributed Parameter Systems
Canada	NATIONAL RESEARCH COUNCIL OF CANADA	Corkum, Paul	Linking Attosecond Science in Solids and Gases
Canada	UNIVERSITY OF TORONTO	Steinberg, Adam	Turbulence Evolution Through Premixed Flames & its Relation w/ Flame Structure
Canada	UNIVERSITY OF OTTAWA	Broadbent, Anne	VERIFICATION OF QUANTUM COMPUTATIONS
Canada	UNIVERSITY OF WATERLOO	Eliasmith, Chris	Learning in large-scale models of biological cognition
Canada	UNIVERSITY OF BRITISH COLUMBIA	Grant, Edward	Quantum and classical measures of molecular ultracold plasma dynamics
Canada	YORK UNIVERSITY	Tsotsos, John	Visual Perception and Reasoning: Integrating Cognitive Programs
Canada	UNIVERSITY OF WATERLOO	Mann, Robert	Through a ring of fire: Information Preservation across Horizons
Canada	ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING	Caines, Peter	New Directions in Mean Field Games: MFG Subpopulation Behaviours and Grapho
Canada	UNIVERSITY OF TORONTO	Thywissen, Joseph	Quantum Simulation of Optical Conductivity
Canada	UNIVERSITY OF TORONTO	Brumer, Paul	Coherent control of cold and ultracold bimolecular reactions
Canada	McMaster University	Bassim, Nabil	Electron Microscopy and Spectroscopy of 2D Hybrid Material Architectures
Canada	UNIVERSITY OF BRITISH COLUMBIA	Poursartip, Anoush	Science-based Automation of Composites Manufacturing
Canada	QUEENS UNIVERSITY AT KINGSTON	Rival, David	Learning to Fly - Using Distributed Pressure Sensing and Network Strategies
Canada	UNIVERSITY OF SASKATCHEWAN	Smolyakov, Andrei	Mechanism(s) of the anomalous electron current and coherent structures
Canada	UNIVERSITY OF TORONTO	Brumer, Paul	Quantum Coherence and Dynamics in Biological Processes: Molecular Isomeriza

Canada	UNIVERSITY OF OTTAWA	Broadbent, Anne	Cryptography in a Quantum World
Canada	DALHOUSIE UNIVERSITY	SELINGER, PETER	Dependent Type Theory for Verified Quantum Software
Canada	QUEEN'S UNIVERSITY AT KINGSTON	PIOMELLI, UGO	Populating the wall layer, one eddy at a time
Chile	Universidad de La Serena	Ramirez, Amelia	Non-Resolved Satellite Multi-Modal Data Fusion
Chile	UNIVERSIDAD DE CHILE	Díaz, Marcos	Ionosphere and Magnetosphere studies using CubeSats
Chile	Pontificia Universidad Catolica de Chile	Maze, Jeronimo	Magneto-Optical Properties of new Emitters in Diamond
Chile	UNIVERSIDAD TECNICA FEDERICO SANTA MARIA	Escobar, Maria-Jose	Improving human vision through artificial systems considering new capabilit
Chile	UNIVERSIDAD DE SANTIAGO DE CHILE	Stepanova, Marina	Study of plasma pressure distribution in the magneto-sphere during geomagnet
Chile	Universidad Autonoma de Chile	Denis Alpizar, Otoniel	Molecular processes at the extreme temp relevant for the hypersonic flight
Chile	Pontificia Universidad Catoli ca de Valparaiso	Vera, Esteban	Development of systems and algorithms for a extreme high resolution compressive
Chile	FUNDACION CIENTIFICA Y CULTURAL BIOCIENCIA	Blamey, Jenny	Deconvolution of a biofilm involved in biocorrosion of metal alloys
Chile	FUNDACION CIENCIA PARA LA VIDA	Perez-Acle, Tomas	Neuromorphic models of the visual system
Chile	FUNDACION CIENTIFICA Y CULTURAL BIOCIENCIA	Blamey, Jenny	Search for a psychrotolerant RNA polymerase promoter-sequence
Chile	UNIVERSIDAD NACIONAL ANDRES BELLO	Castro Nallar, Eduardo	Evolving at Life’s Limits - Microbial Communities in Chile’s Extreme Environment
Chile	UNIVERSIDAD DE CHILE	Alejandro, Juan	Study the simultaneous variation of the Ionosphere, GNSS
Chile	UNIVERSIDAD DE CHILE	Dulic, Diana	Study of the response to the space environment conditions of graphene
Chile	FUNDACION CIENCIA PARA LA VIDA	Perez-Acle, Tomas	Covid19GeoModeller (C19GM-US): a georeferenced model to study the dispersion
Chile	Instituto de Neurociencia Biomedica (BNI)	HETZ, CLAUDIO	Coping with environmental stress: interphase between neuronal proteostasis & brain physiology

Colombia	UNIVERSIDAD DE LOS ANDES	Quijano, Nicanor	DDDAS Anomaly Detection and Response
Colombia	UNIVERSIDAD INDUSTRIAL DE SANTANDER UIS	ARGUELLO FUENTES, HENRY	Infrared color-coded aperture optimization for object tracking
Costa Rica	UNIVERSIDAD DE COSTA RICA	LESSER-ROJAS, LEONARDO	Investigating energy transfer phenomena in novel organo-metallic nanomaterials and metal-binding biomacromolec
Croatia	FAKULTET ELEKTROTEHNIKE I RACUNARSTVA	Hrabar, Silvio	Non-Foster Networks for Tunable and Wideband RF Devices
Cyprus	RESEARCH FOUNDATION P.L LIMITED	Drikakis, Dimitris	Hypersonic Acoustic Loading (HAL)
Czechia	CZECH TECHNICAL UNIVERSITY IN PRAGUE	Pevny, Tomas	Using Deep Reinforcement Learning to Simulate Security Analyst
Denmark	AARHUS UNIVERSITET	Spitters, Bas	Homotopy type Theory and Probabilistic Computation
Ecuador	UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ	VALAREZO, ALFREDO	3D Thermo-Mechanical Modeling of Multilayered TBC s for Gas Turbine Engines
Ecuador	UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ	Caicedo, Andres	Skin UVR damage protection is mediated by the mitochondrial transfer
Fiji	University of South Pacific	Kumar, Sushil	Ionosphere irregularities in South Pacific
Fiji	University of South Pacific	Kumar, Sushil	Kiritimati Equatorial Ionospheric Observatory (KEIO): Upper atmospheric obs
Finland	Tampereen korkeakoulusäätiö sr	Hokka, Mikko	Simultaneous Deformation & Temp Measurements in High Rate Events
France	Centralesupelec	Rontani, Damien	Spatio-temporal photonic liquid state and extreme learning machines
France	Universite De Lorraine	ASSOUAR, BADREDDINE	Acoustic Metasurfaces: A transformative Approach for Low-Freq
France	Institut Mines Telecom	Grillot, Frederic	Controlling nonlinear dynamics for high-power lasers and optical countermeasures
France	Fondat J J Laffont Tlse Sciences Eco	Bolte, Jerome	Towards a theory of long-step algorithms for large scale optimization
France	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS-DELEGATION PARIS	Frankowska, Hélène	From vector spaces to hyperspaces, hypermaps and relations

France	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS-DELEGATION PARIS	Rejiba, Faycal	Geophysical soil modeling
France	Fondat J J Laffont Tlse Sciences Eco	Bolte, Jerome	Landscapes of large scale problems with applications to machine learning
France	COMMISSARIAT L'ENERGIE ATOMIQUUSE	Douillard, Ludovic	Physics Of Electron Emitting MaterialS (POEEMS)
France	SORBONNE UNIVERSITE	Trelat, Emmanuel	Autonomous guidance and targeting by semi-algebraic methods
France	EURECOM	Francillon, Aurélien	Cross-Abstraction Analysis for Embedded Systems
France	UNIVERSITE D'AIX MARSEILLE	Dupont, Pierre	Mach number independent hot-wire anemometry
France	ECOLE NATIONALE DES PONTS ET CHAUSSEES	Le Bris, Claude	Multiscale materials science: a math approach to defects
France	COMMISSARIAT L'ENERGIE ATOMIQUUSE	Barrett, Nicholas	Ferroelectric control of conductivity in beta-Ga2O3 for power electronics
France	CENTRALE LILLE INSTITUT	VASSILICOS, JOHN-CHRISTOS	Non-equilibrium cascade and large-scale dynamics in wall turbulence
Germany	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT E.V.	Wagner, Alexander	Experimental Hypersonic Shock Boundary-Layer Interaction Studies on a Flat Plate
Germany	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT E.V.	Krumbein, Andreas	Improvement of Physical Modeling for Vortex-Dominated Flows
Germany	TECHNISCHE UNIVERSITAET BERLIN	Gramann, Klaus	Neural Markers of SA
Germany	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT Ev	Kirchhartz, Rainer	Boundary Layer Transition Experiment II (BOLT II)
Germany	Technische Universität Darmstadt	Klein, Andreas	Controlling resistance degradation of high permitivity dielectrics by bulk &interface
Germany	Universitat Paderborn	Lorenz, Alexander	Liquid crystal light valves driven by photovoltaic fields: Continuation
Germany	Humboldt-Universitat zu Berlin	Masselink, William	Developof High- Brightness Continuous-Wave Mid-Infrared Quantum-Cascade Laser
Germany	Universität zu Lübeck	Vogel, Alfred	Multimodal sensing of ultra-high-resolution free-electron-mediated modification
Germany	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV	Thiele, Thomas	Transition Experiments on BOLT-Modell in H2K

Germany	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV	Guelhan, Ali	Study of SWBLI on the STORT Configuration
Germany	UNIVERSITAET DER BUNDESWEHR MUENCHEN	Gerdts, Matthias	Dynamic scheduling of interacting automated VTOLs
Germany	FORSCHUNGSVERBUND BERLIN E.V.	Petrov, Valentin	Growth of novel NLO materials for QPM frequency conversion in the MLWIR
Germany	Ludwig-Maximilians-Universität München	RÜHRMAIR, ULRICH	Highly Secure Nonlinear Optical PUFs
Germany	Technische Universität Dresden	TAJMAR, MARTIN	Novel Air-Breathing Ion Propulsion for Space Vehicle in Low Earth Orbit
Germany	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT E.V.	DAUB, DENNIS	Experiments on Hypersonic Fluid-Structure Interaction in the Wind Tunnel H2K
Greece	NATIONAL CENTER FOR SCIENTIFIC RESEARCH 'DEMOKRITOS'	Speliotis, Athanassios	Linear galvanomagnetic thin films
Greece	NATIONAL OBSERVATORY OF ATHENS	Belehaki, Anna	Spatial Trajectory of TIDs
Hungary	KOZEP-EUROPAI EGYETEM	Iniguez, Gerardo	Harness effects of algorithmic bias in online social networks
Iceland	HASKOLINN I REYKJAVIK EHF	Valfells, Agust	Molecular dynamics simulation for electron emission in cathode nano-structures
India	INSTITUTE OF RADIO PHYSICS & ELECTRONICS	Paul, Ashik	Predicting Signal Outage Due to Ionosphere
India	INSTITUTE FOR PLASMA RESEARCH	Sen, Abhijit	Fore-Wake Excitations from Orbiting Space Debris
India	INDIAN INSTITUTE OF SCIENCE	Nath, Digbijoy	Growth and study of optical properties of ε-Ga_2O_3
India	INDIAN INSTITUTE OF SCIENCE	Tiwary, Chandra Sekhar	3D printing of 2 dimensional materials for robust electronics
India	INDIAN INSTITUTE OF SCIENCE	Singh, Vibhor	Develop of superconducting hybrid optomechanical system
India	INDIAN INSTITUTE OF TECHNOLOGY BOMBAY	TALLUR, SIDDHARTH	High speed nano-photonics enabled by 2DEG in AlGaAs/GaAs heterostructures
India	INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR	KOCHAT, VIDYA	Large area 2D heterostructures based on vander Waals epitaxy
India	INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH	RAMANATHAN, VAIDHYANATHAN	Integrating Organic Quantum Dots into Covalent Organic Frameworks Conducting Polymers

India	INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH	NAIR, SUNIL	Investigating magnetoelectric multiglasses using nonlinear dielectric & magnetic
Ireland	UNIVERSITY OF DUBLIN, TRINITY COLLEGE	Marchetti, Nicola	Internet of Complex Things
Ireland	UNIVERSITY OF DUBLIN, TRINITY COLLEGE	Murray, Sophie	Seeking the source of solar eruptions
Ireland	UNIVERSITY COLLEGE CORK	Cryan, John	Microbiome-Gut-Brain axis, Brain Function and Behaviour
Ireland	UNIVERSITY OF DUBLIN, TRINITY COLLEGE	Ryan, Tomas	Innate Memory - the Plasticity of Instinct
Israel	WEIZMANN INSTITUTE OF SCIENCE	Maron, Yitzhak	Properties of imploding plasma magnetic-field distributions
Israel	The Interdisciplinary Center (IDC) Herzliya	Boyle, Elette	Secure Computation via Function Secret Sharing
Israel	TECHNION ISRAEL INSTITUTE OF TECHNOLOGY	SEGEV, MORDECHAI	Advances in Metamaterials
Israel	BEN GURION UNIVERSITY OF THE NEGEV	Rosenwaks, Salman	Theoretical studies of fundamental processes relevant to diode pumped alkali lasers
Israel	BEN GURION UNIVERSITY OF THE NEGEV	Rosenwaks, Salman	Improving Diode Pumped Alkali Laser Beam Quality by Refractive Index Gradients
Israel	TECHNION R & D FOUNDATION LTD.	Talmon, Yeshayahu	Synthesis and Character of BNNTs for Lightweight Aerospace Fibers
Israel	TECHNION ISRAEL INSTITUTE OF TECHNOLOGY	Shima, Tal	Guidance for Swarm Engagements
Israel	HEBREW UNIVERSITY OF JERULEM (THE)	LEVY, URIEL	Chip scale integrated quantum platform
Israel	SOREQ - NAHAL SOREQ NUCLEAR RESEARCH CENTER	Gvishi, Raz	Additive manufacturing with sol-gel
Israel	TEL AVIV UNIVERSITY	Scheuer, Jacob	Light Amplification in the Frozen Mode Regime
Israel	TECHNION R & D FOUNDATION LTD.	RITTEL, DANIEL	Mechanics and physics of dynamic localization & fracture in heterogeneous ductile materials
Israel	TEL AVIV UNIVERSITY	GAZIT, EHUD	Functional Materials Based on Amino Acid Supramolecular Assemblies
Israel	HEBREW UNIVERSITY OF JERULEM (THE)	Etgar, Lioz	Synthesis and characterization of two dimensional hybrid organo-metal halide perovskite

Israel	WEIZMANN INSTITUTE OF SCIENCE	Kronik, Leeor	Predicting electro-optic 2D materials properties using TD-DFT hybrid functionals
Israel	TEL AVIV UNIVERSITY	Bisker, Gili	Quantifying nonequilibrium dynamics of stochastic systems with partial info
Israel	The Interdisciplinary Center (IDC) Herzliya	BOYLE, ELETTE	New Advances in Secure Multi-Party Computation
Israel	TEL AVIV UNIVERSITY	DVIR, TAL	Engineering a motile, controllable intestine with integrated electronic to study host-microbiome interact
Israel	TECHNION RESEARCH & DEVELOPMENT FOUNDATION LTD.	SHIMA, TAL	Virtual Target Approach to Multi-Threat Guidance and Weapon-Target Assignment
Israel	SHENKAR COLLEGE OF ENGINEERING AND DESIGN	SHEFFER, EYAL	Conductive technical fabrics composed of Carbon-Nanotube yarns
Italy	ALMA MATER STUDIORUM UNIVERSITA' DI BOLOGNA	Roverato, Alberto	Path weights in undirected Markov random fields
Italy	UNIVERSITA' DEGLI STUDI DI ROMA LA SAPIENZA	Di Nocera, Francesco	Eye fixations as a measure of task demand and trigger for adaptive automation
Italy	CNR IMIP BARI, Consiglio Nazionale Delle Ricerche Isti	De Sio, Luciano	Thermo-plasmonics in self-organized materials
Italy	UNIVERSIT DEGLI STUDI DI GENOVA	Lorenzo, Rosasco	OPTiMaL Optimization for Machine Learning- Robustness
Italy	CONSIGLIO NAZIONALE DELLE RICERCHE	Guarino, Vincenzo	Three dimensional brain in vitro models via electrofluidodynamics
Italy	UNIVERSITA' DEGLI STUDI DI PALERMO	Chella, Antonio	Robot Inner Speech for Trust
Italy	UNIVERSITA' DEGLI STUDI DI ROMA LA SAPIENZA	Pirozzoli, Sergio	Hi-fi simulations of hypersonic 3-D SWBLIs
Italy	UNIVERSITA' DI PISA	Filippeschi, Sauro	Design criteria & prediction tool based on a multi-parameters of pulsating heat pipes
Italy	ALMA MATER STUDIORUM UNIVERSITA' DI BOLOGNA SEDE	Monaci, Michele	Advanced solution methodologies for loading and transportation problems
Italy	ALMA MATER STUDIORUM UNIVERSITA' DI BOLOGNA SEDE	Malaguti, Enrico	Network protection, interdiction and design under uncertainty
Italy	UNIVERSITA' DEGLI STUDI DI ROMA LA SAPIENZA	Lacarbonara, Walter	A high damping cellular material with nanocomposite web vibration absorbers

Italy	UNIVERSIT DEGLI STUDI DI GENOVA	Noceti, Nicoletta	Cognitively-inspired architectures for human motion understanding
Italy	UNIVERSIT DEGLI STUDI DI GENOVA	Santacesaria, Matteo	MALIP, Machine Learning for Inverse Problems
Italy	UNIVERSIT DEGLI STUDI DI GENOVA	Rosasco, Lorenzo	Machine learning approaches to navigate turbulence
Italy	UNIVERSITA DEGLI STUDI DI ROMA TRE	Lanzara, Giulia	Hierarchical Muscular System for Textured Morphing Composites
Italy	CONSIGLIO NAZIONALE DELLE RICERCHE	Benfenati, Valentina	Shining light for sensing and control of astrocytes microdomains structure,
Italy	UNIVERSITA' DEGLI STUDI DI NAPOLI FEDERICO II	D'ANNA, ANDREA	Coke, Soot, and Interstellar Carbon Dust: Optoelectronic Signatures of Nano-Carbon
Italy	ALMA MATER STUDIORUM - UNIVERSITA' DI BOLOGNA	VIGO, DANIELE	Efficient Solution of Large-Scale Vehicle Routing Problems
Italy	CONSIGLIO NAZIONALE DELLE RICERCHE - CNR	CONVERTINO, ANNALISA	Investigation on Co-cultured Astrocyte and neuron populations
Japan	JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY	Principal Investigator	Computational Studies on Phonon Engr of Transition Metal
Japan	CENTER FOR COLLABORATIVE INTERDISCIPLINARY SCIENCES N.P.O.	Principal Investigator	2D Magnetic Heterostructures & Appl of TOMBO Code to Hyperfine Structures
Japan	KANAZAWA INSTITUTE OF TECHNOLOGY	Principal Investigator	Statistical Fatigue Failure Time of Unidirectional CFRP under Compression...
Japan	JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY	Principal Investigator	Developing/Verifying Autonomy Required for IOT-assisted Users
Japan	KEIO UNIVERSITY	Principal Investigator	Practical Graph States in Low-Bandwidth, Noisy Quantum Networks
Japan	JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY	Principal Investigator	A Study on constructing knowledge graph and Graph-based Deep Learning
Japan	JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY	Principal Investigator	LANDrone: Developing robotic tools for adding non-planar surface landing capabil
Japan	JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECH	Principal Investigator	Computational Characterizations of High-Entropy Alloys
Japan	KANAZAWA INSTITUTE OF TECHNOLOGY	Principal Investigator	Quality Estimation during CFRTP Press Molding by Machine Learning of Condition M

Japan	TAMAGAWA UNIVERSITY	Principal Investigator	Control of Quantum Noise for Optical Sensing & Communications
Japan	RIKEN	Principal Investigator	Studies on light-light and light-matter interactions, with a focus on interferometry
Japan	CENTER FOR COLLABORATIVE INTERDISCIPLINARY SCIENCES, N.P.O.	Principal Investigator	Pressure, Ion Probe, and Flow-Visualization Measurements in Inside-injector Rotating Detonation Engines
Korea	Soongsil University Industry-Academic Cooperat	Huh, Wansoo	On-Demand Stoichiometry Control of Copper Sulfide Nanocrystals with Omni-Tunable Semiconductor Properties
Korea	KOREA RESEARCH INSTITUTE OF STANDARDS AND SCIENCE (KRISS)	Lee, Sang Jun	Achieve the multi-functional infrared sensors technologies for multi-spectral and polarimetric infrared images
Korea	Inha University Research and Business Foundation	Wie, Jeong	Reversibly Reconfigurable 3D Micro- and Nano- Photonic Devices
Korea	HANYANG INDUSTRY-UNIVERSITY COOPERATION	Park, Won	Programming of Graphene Properties via Defect Design and Characterization
Korea	Korea Advanced Institute of Science and Technology	Kong, Hong Jin	Development of SBS-PCM for high power laser
Korea	SEOUL NATIONAL UNIVERSITY	Piao, Yuanzhe	Novel multi-ferroic nanoparticle-based stretchable composite metamaterials
Korea	Chungnam National Univ	Kim, Yong Ha	3D Mid-Latitude Scintillation
Korea	PUSAN NATIONAL UNIVERSITY	Kim, Sangkil	mmWave Nano-sensor
Korea	Korea University Research and Business Foundation	Ko, Hanseok	Ground robot to autonomously navigate
Korea	Korea Advanced Institute of Science and Technology	Hong, Soon Hyung	High Temperature Deformation Behavior and Strengthening Mechanisms
Korea	Electronics and Telecommunications Research Institute	Yi, Sungwon	Foundational Aspects of Machine Learning in Multi-Agent Online Games as Serious Games
Korea	Sungkyunkwan University Research & Business	Suhr, Jonghwan	Sandwich Composites with Bamboo Fiber by using Additive Manufacturing
Korea	Korea Advanced Institute of Science and Technology	Suh, Changho	Validating Simulator-based Learning via Interpretation

Korea	Sungkyunkwan University Research & Business	Nam, Jae-Do	Electromagnetic Interference (EMI) Shielding
Korea	Seoul National University of Science and Technology	Chung, Jae-Young	Development of broad RF materials measurement
Korea	Sungkyunkwan University Research & Business	Suhr, Jonghwan	Sustainable Soda Lignin-PLA 3D Printable Biocomposite Materials
Korea	Inha University Research and Business Foundation	Wie, Jeong	Responsive Substrates Toward Mobilization of Liquid Metal RF Devices
Korea	Pohang University of Science and Technology	Cho, Gil Young	Theory of Non-Linear 2D Spectroscopy for Topological Quantum Matter
Korea	KYUNG HEE UNIVERSITY	Lee, Jin-Yi	Ion Composition Prop in Interplanetary CME & Post-CME Current Sheet
Korea	Korea Advanced Institute of Science and Technology	Kim, Yongdae	Cyber Physical Analysis of S/W Survivability by Stimulating Sensors on Drones
Korea	SEOUL NATIONAL UNIVERSITY	Song, Hyun Oh	Classification Attack Detection via Class-specific Visual Context Optimization
Korea	Korea Advanced Institute of Science and Technology	Choo, Jaegul	Knowledge Externalization from Image-to-Image Translation
Korea	SAHMYOOK UNIVERSITY INDUSTRY-ACADEMY COOPERATION FOUNDATION	Lee, Jangmee	Dashboard Design through Data Visualization (D3V) with big data analysis
Korea	Ewha University-Industry Collaboration Foundation	Bae, YuJeong	Spin resonance studies of single molecule qubits
Korea	SEOUL NATIONAL UNIVERSITY	Do, Hyungrok	n-LIBS for Measurements in High-Speed Flows
Korea	University of Seoul industry cooperation foundation	LEE, JU HAN	Investigation into an optimum device structure for cladding light removal in high power fiber lasers
Korea	SEOUL NATIONAL UNIVERSITY	Yun, Gunjin	Vitrimer Nanocomposites Modeling
Korea	KOREATECH Industry	Kim, Suk Jun	Stable Li metal anode for high-capacity rechargeable batteries
Korea	Sungkyunkwan University Research & Business	Jeong, Mun Seok	Quantitative Prediction Electrical Properties with Optical Measurement with AI
Korea	Soongsil University Industry-Academic Cooperat	HUH, WANSOO	Stoichiometric Doping of Copper Sulfide Nanocrystals Assemblies with Tunable Electronic Properties

Korea	University of seoul industry cooperation foundation	AHN, DAVID	Quantum Algorithm Optimization using quantum Karnaugh Map
Korea	Korea Advanced Institute of Science and Technology	RA, YOUNGSIK	Synthetic Remediation Biology: Asgard Detoxification of Synthetic Firefighting Foam
Korea	Korea Advanced Institute of Science and Technology	RYU, KWANGSUN	Develop of platform-independent plasma probe for cubesats
Luxembourg	Université du Luxembourg Etabl. Public	Rudykh, Stephan	Architectured Magnetoactive Elastomers: Functionalities through Instabilities
Malaysia	University of Malaya	Chew, Kian-Hooi	All-electron Mixed Basis Calculations of Monolayer Ilmenite
Malaysia	UNIVERSITI KEBANGSAAN MALAYSIA	Nordin, Rosdiadee	Optimization with edge intelligence
Malaysia	University of Malaya	JEONG, HEEJEONG	Randomly disordered-topological edge-state of rydberg atom array
Malaysia	INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA	AZLAN, NORSINNIRA	Stretchable Strain Sensor for Hand Pose Recognition Under Dexterous Articulation
Malaysia	UNIVERSITI KEBANGSAAN MALAYSIA	ABU-SAMAH, ASMA	Context-aware Vertical Handover forBeyond 5G Wireless Hetero Networks
Mexico	Centro de Investigacione en Optica	Strojnik, Marija	Rotationally shearing interferometer for extra-solar system planet detection
Mexico	CIQA	Ziolo, Ronald	Perylene bisimide-conjugated oligomer dyes
Mexico	Universidad Nacional Autónoma de México	U'REN, ALFRED	Optical Analogs of Hawking Radiation in the Quantum Regime
Netherlands	TECHNISCHE UNIVERSITEIT DELFT	Bisagni, Chiara	Multi-Point Test Method and Numerical Modeling for Damage-Tolerant Composites
Netherlands	Netherlands Organisation for Applied Scientific Research	VAN LINGEN, JOOST	Gradient Additive Manufacturing of Energetics Research (GAMER)
Netherlands	Netherlands Organisation for Applied Scientific Research (TNO)	Brouwer, Anne-Marie	Multimodal eye fixation related brain state analysis for attention and emotion
Netherlands	Zander Laboratories B.V.	Zander, Thorsten	Universal Classification of Mental Workload (UNILOAD)
Netherlands	UNIVERSITEIT VAN AMSTERDAM	Groth, Paul	Situated Multimodal Dialogue
Netherlands	TECHNISCHE UNIVERSITEIT DELFT	de Croon, Guido	SNNs autopilot for UAS
New Zealand	THE UNIVERSITY OF AUCKLAND	Cater, John	Magnetic Thrust Vectoring

New Zealand	THE UNIVERSITY OF AUCKLAND	JONES-TODD, CHARLOTTE	Spatiotemporal dependency structures and network distances in point processes.
Norway	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET	ALEXIS, KOSTAS	RESNAV: Resilient Assured Learning-based Autonomous Navigation
Portugal	INEB - INSTITUTO NACIONAL DE ENGENHARIA BIOMÉDICA	Pego, Ana Paula	STRESS - Towards the study of the impact of environmental mechanostimulus
S. Africa	UNIVERSITY OF CAPE TOWN	GOVENDER, REUBEN	Unpacking blast fragment and pressure wave contributions to target deformation
Singapore	Singapore University of Technology and Design	Fitzsimons, Joseph	Primitives for Quantum Enabled Security
Singapore	NANYANG TECHNOLOGICAL UNIVERSITY	Lim, Sierin	Investigation on the Tuneable Optical Properties of Reformatted Bacterial Cellul
Singapore	NATIONAL UNIVERSITY OF SINGAPORE	Yew, Wen Shan	Asgard Detoxification of Synthetic Firefighting Foam
Singapore	NATIONAL UNIVERSITY OF SINGAPORE	DUMKE, RAINER	Synthetic 2D Materials for Quantum Light Sources & Memory
Singapore	NATIONAL UNIVERSITY OF SINGAPORE	LING, ALEXANDER	Scalable AWG with fast feedback option for medium scale quantum processor
Singapore	NATIONAL UNIVERSITY OF SINGAPORE	van Kan, Jeroen	Evaluating high resolution in vivo proton imaging at nanoscale
Singapore	NATIONAL UNIVERSITY OF SINGAPORE	KOPERSKI, MACIEJ	Designing quantum systems with radiative centers in two-dimensional materials.
Slovenia	UNIVERSITY OF LJUBLJANA	Belusic, Gregor	Polarization vision in insects
Slovenia	UNIVERSITY OF LJUBLJANA	BAUER, ANDREJ	Type Theory for Data-Intensive Formalization
Spain	FUNDACION IMDEA MATERIALES	Vilatela, Juan	Exploiting properties of CNT yarns for charge transfer and storage
Spain	UNIVERSIDAD COMPLUTENSE DE MADRID	Mendez, Bianchi	Properties of gallia micro and nanotructures
Spain	FUNDACION IMDEA MATERIALES	Gonzalez, Carlos	Multiscale Virtual Testing of Composites
Spain	UNIVERSIDAD CARLOS III DE MADRID	RODRIGUEZ-MARTINEZ, JOSE	The mechanics and physics of dynamic localization and fracture in heterogeneous ductile materials
Spain	AGENCIA ESTATAL CONSEJO SUPERIOR INVESTIGACIONES CIENTIFICAS	RIOS, DAVID	Robust Command and Control under Adversarially Perturbed Data

Spain	UNIVERSIDAD DE SEVILLA	FRANCO, VICTORINO	Hysteresis and frequency response as limiting factors for efficient thermomagnetic energy conversio
Sri Lanka	UNIVERSITY OF PERADENIYA	RAJAPAKSE, RAJAPAKSE MUDIYANSELAGE	Tuning optical and electronic properties via molecular engineering of photon
Sweden	STOCKHOLMS UNIVERSITET	Thomas, Richard	Probing reactions on the atomic level
Sweden	KUNGLIGA TEKNISKA HOGSKOLAN	Norman, Patrick	Cholesteric Liquid Crystal Glasses for Nonlinear Optics
Sweden	Royal Institute of Technology	LOURDODOSS, SEBASTIAN	Heteroepitaxial growth and study of nonlinear optical materials
Sweden	CHALMERS TEKNISKA HOGSKOLA AB	ASP, LEIF	Reaslising Structural Battery Composites
Sweden	KUNGLIGA TEKNISKA HOGSKOLAN	ZENKERT, DAN	Structural Battery Composites
Switzerland	UNIVERSITAT BASEL	Meuwly, Markus	Reactive Collisions and Final State Analysis of C- and O- Reactions of Hypersonic Flight
Switzerland	Ecole Polytechnique Fédérale de Lausanne	Kippenberg, Tobias	Nonreciprocity in Integrated Optical and Microwave Optomechanical Based Systems
Switzerland	Ecole Polytechnique Fédérale de Lausanne	Kippenberg, Tobias	Exploring dynamics and applications of temporal Kerr soliton frequency comb
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Switzerland	Geneva Foundation, The	BATCHINSKY, ANDRIY	Minimally invasive acuity indexes for prolonged field care in trauma patients
Switzerland	Ecole Polytechnique Fédérale de Lausanne	Osterwalder, Andreas	Studying chemi-ionisation of state-selected lanthanides with O(3P) in beams
Switzerland	EIDGENOSSISCHE TECHNISCHE HOCHSCHULE	KOVALENKO, MAKSYM	On-demand, Single and N-Photons Sources by Perovskite Q-Dots
Switzerland	UNIVERSITAT BASEL	MEUWLY, MARKUS	Machine Learning for Chem Reaction Dynamics in HEnergy, Rarefied Gas Flow
Switzerland	Ecole Polytechnique Fédérale de Lausanne	KIPPENBERG, TOBIAS	Exploration of Levy Statistics in Random modulation parallel
Taiwan	NATIONAL CENTRAL UNIVERSITY	Tsai, Lung-Chih	Ionospheric Irregularities over Taiwan
Taiwan	NATIONAL TAIWAN UNIVERSITY	Lin, Chung-Wei	Robustness Verification for System under Denial-of-Service Attacks

Taiwan	NATIONAL TAIWAN UNIVERSITY	Kiang, Jean-Fu	Bistatic Radar Clutter
Taiwan	NATIONAL TAIWAN UNIVERSITY	Goan, Hsi-Sheng	Quantum control and quantum computing
Taiwan	NATIONAL TAIWAN UNIVERSITY OF SCIENCE AND TECHNOLOGY	HOU, HUEI-TSE	Collaborative decision making: Evaluations of methodologies and cognitive design
Taiwan	NATIONAL TAIWAN UNIVERSITY	Wu, Pei-Yuan	Study of Privacy Preservation Techniques for Deep Learning
Taiwan	NATIONAL CHUNG HSING UNIVERSITY	Chung, Ming-Chiang	Determination of topological quantities
Taiwan	ACADEMIA SINICA	Chung, Kai-Min	Secure Multiparty Quantum Computation
Taiwan	NATIONAL TAIWAN UNIVERSITY	Wu, Hsuan-Chen	Cell-Free Synthetic Biology & Biofabrication for Novel Silk Biomaterials Develop
Taiwan	National Sun Yat-Sen University	Lin, Tsung-Hsien	1D and 3D Soft Chiral Photonic Crystals
Taiwan	NATIONAL TAIWAN UNIVERSITY	Cheng, Hung Hsiang	All group IV photodetector (graphene/oxide/GeSn film)
Taiwan	NATIONAL CHUNG HSING UNIVERSITY	Tsai, Ming-Hung	Design of refractory high entropy superalloys
Taiwan	NATIONAL CHENG KUNG UNIVERSITY	HWANG, SHENG-KWANG	FMCW and Chaotic Microwave Gen Using Nonlinear Photonic Systems for V- and W-Band Radar
Thailand	King Mongkut's University of Technology North Bangkok	Boonpoonga, Akkarat	Simulation of Radar
Thailand	SCIENCE AND TECHNOLOGY PARK, CHIANG MAI UNIVERSITY	Sawangrat, Choncharoen	The mechanistic study of plasma-activated solution on other chemicals
Turkey	SABANCI UNIVERSITESI	Sendur, Kursat	Broadband Reflective Surfaces for Infrared Radiation
Turkey	SABANCI UNIVERSITESI	Sendur, Kursat	Surface Roughness Effects in Reflection and Emission of Infrared Radiation
Turkey	GEBZE TEKNIK UNIVERSITESI TEKNOLOJI TRANSFER OFISI	MENSUR ALKOY, EBRU	Study Effect of Crystallographic Anisotropy and Defects
Turkey	TOBB EKONOMI VE TEKNOLOJI UNIVERSITESI	Buke, Goknur	2D Metal Carbides for EM Shielding
Turkey	ORTA DOGU TEKNIK UNIVERSITESI	Kalay, Eren	Metallic Glass/Nanocrystal Composites and NiTiHf Shape Memory Alloys for Hi
Turkey	BILKENT UNIVERSITESI	OKAY, CIHAN	Topology of quantum resources: theories for quantum information and computing

Turkey	IZMIR YUKSEK TEKNOLOJI ENSTITUSU	SEVINCLI, HALDUN	Quantum Magnetotransport in Two-Dimensional Quartic Materials
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U.K.	THE ROYAL VETERINARY COLLEGE	Bomphrey, Richard	Avian-Inspired Multifunctional Morphing Air Vehicles:
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U.K.	UNIVERSITY OF STRATHCLYDE VIZ ROYAL COLLEGE OF SCIENCE & TECH	Daley, Andrew John	Engineering many-body quantum states and dissipative dynamics in quantum
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U.K.	THE UNIVERSITY OF OXFORD	McGilvray, Matthew	Hypersonic Intake Testing with Varying Wall Temperature
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U.K.	UNIVERSITY OF LANCASTER	Marshall, Andrew	MWIR LED research for scene generation arrays
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U.K.	UNIVERSITY OF MANCHESTER	Cangelosi, Angelo	Trust in Human Robot Interaction Via Embodiment (THRIVE ++)
U.K.	UNIVERSITY OF STRATHCLYDE VIZ ROYAL COLLEGE OF SCIENCE & TECH	Oterkus, Erkan	Determination of the Length Scale Parameter in Peridynamics
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U.K.	UNIVERSITY OF STRATHCLYDE VIZ ROYAL COLLEGE OF SCIENCE & TECH	Akartunali, Kerem	Multi-Level Robust Optimization: Theory, Algorithms and Practice
U.K.	UNIVERSITY OF WARWICK	Pollacco, Don	Optical lightcurves of LEO spacecraft: Machine learning techniques
U.K.	UNIVERSITY COLLEGE LONDON	Alfe, Dario	High accuracy simulation methods for realistic materials modelling
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U.K.	UNIVERSITY OF STRATHCLYDE VIZ ROYAL COLLEGE OF SCIENCE & TECH	Jaroszynski, Dino	Research and Design of a Diode Pumped Pulsed CO2 Ultra-Intense Laser
U.K.	UNIVERSITY OF SHEFFIELD, DEPARTMENT OF PSYCHOLOGY	Clarke, Sam	Wide-field fireball spectroscopy
U.K.	Liverpool John Moores University	Tammas-Williams, Samuel	Laser Powder Bed Fusion of Ti 6Al-4V
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U.K.	UNIVERSITY OF SOUTHAMPTON	GANAPATHISUBRAMANI, BHARATHRAM	Experimental study of turbulent flow over permeable rough surfaces
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U.K.	IMPERIAL COLLEGE London	Holm, Darryl	Fluid dynamics of geometric rough flows
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U.K.	THE ROYAL VETERINARY COLLEGE	Bomphrey, Richard	Multimode Sense and Avoid
U.K.	CRANFIELD UNIVERSITY	Shin, Hyo-Sang	Decision Making for Autonomous Systems
U.K.	UK RESEARCH & INNOVATION	Horne, Richard	Simulating the outer radiation belt
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U.K.	Imperial College Of Science, Technology & Medicine	Specia, Lucia	Multimodal Machine Translation
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U.K.	THE UNIVERISTY OF CAMBRIDGE	Wall, Aron	Tensor Networks and Holographic Spacetime
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U.K.	Imperial College of Science, Technology & Medicine	RIGAS, GEORGIOS	Nonlinear Flow Receptivity in Shock-Wave Boundary-Layer Interaction
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Ukraine	Science And Technology Center In Ukraine	Morozovskaya, Anna	Controlling ferroelectricity in Nano-sized Core-shell Type Particles
Viet Nam	International University Vietnam National University	Ly, Le	Generic Multi-task Learning Framework for Mixed Data
Viet Nam	Hanoi University Of Science And Technology	Tran, Thanh Hai	Edge Intelligence based Hand Gestures Recognition

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