EOARD

Space Research

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Lt Col Kevin Bollino, USAF, PhD
International Program Officer for Space Technology & Control Sciences

European Office of Aerospace Research & Dev (EOARD)
Air Force Office of Scientific Research (AFOSR)
Overview

• Air Force Office of Scientific Research (AFOSR)
• European Office of Aerospace Research and Development (EOARD)
• EOARD Mission / Activities
• Research Interests / Highlights
• How to work with EOARD
AFOSR Today

“The first essential of airpower is preeminence in research.”

General Hap Arnold, “Founding Father of the USAF” (1944)

AFOSR discovers, shapes, & champions basic science to profoundly impact the future Air Force

“Research Interests of the AFOSR” Broad Agency Announcement at www.afosr.af.mil

Basic Science Program Office

- Dynamical Systems & Control
- Quantum & Non-equilibrium Processes
- Information, Decision, & Complex Networks
- Complex Materials & Devices
- Energy, Power, & Propulsion

International Science Program Office
AFOSR Overseas Offices

**European Office of Aerospace R&D (EOARD)**
- 1952: Established as EOAR in Brussels
- 1956: 146 active contracts in 14 countries
- 1970: Collocates with Army/Navy in London
- 1974: Reassigned as detachment to AFOSR

**Asian Office of Aerospace R&D (AOARD)**
- 1974: AOARD established in Tokyo

**Southern Office of Aerospace R&D (SOARD)**
- 2010: SOARD established in Santiago

**MISSION:**
Provide the US Air Force a strategy, awareness, and access to overseas basic research.

**Research Projects**
Grants/contracts to support fundamental S&T of AF interest
179 new projects in FY12

**Conference Support**
Focused support of conferences, workshops, and program reviews
72 events in FY12

**Windows on Science**
Travel support for international researchers to interact with DoD
171 visitors in FY12
EOARD Mission

Building International Relationships

Portfolios
- Aeronautical Sciences
- Ops Research & Math
- Information Sciences
- Materials & Nanotechnology
- Space Technology & Controls
- Physics
- Lasers & EO
- Adv. Aerospace Structures
- Space Sciences

EOARD’s AOR

- Building international goodwill
- Strengthening partnerships
- Avoiding technological surprise
- Accelerating S&T achievements and transitions to the U.S.
Global R&D Today

- US share declining
- 80% of researchers are outside US
- Importance recognized by DoD & AF
  - Future Directions workshops
  - AF/ST Global Horizons study
  - Defense Science Board

In order to avoid technological surprise, it is important for DoD to be involved in the cutting edge of basic research on topics of specific interest to the Department—whether the cutting edge is in the U.S. or overseas. – DSB, Jan 2012
AFOSR Programs Most Aligned with Space Tech/Control Sci of Interest

Space Power and Propulsion

Space Sciences

Remote Sensing and Imaging Physics

Dynamics and Control

Computational Mathematics

Distributed Intelligence and Information Fusion

Optimization and Discrete Mathematics

International Programs

Overviews (including contacts & videos) for these and other programs at:  
https://community.apan.org/afosr/w/researchareas/default.aspx
EOARD Space Focus Areas

**Space Sciences: Lt Col Brad Thompson**
- Space Structures
- Thermal Control
- Propulsion
- Space Situational Awareness (SSA)

**Physics: Lt Col Scott Dudley**
- Space Weather
- Remote Sensing & Imaging
- Plasma Physics & Chemistry
- Physics of Satellite Communications

**Space Technology & Controls: Lt Col Kevin Bollino**
- Space Vehicle Technologies & Engineering
- Astrodynamics
- Remote Sensing & Imaging
- Robotics & Autonomy
- Responsive Space

**Space Sciences: Dr. Tom Caudill**
- Solar storm prediction/transport
- Plasma Physics & Chemistry
- Ionospheric structure and scintillation
- Thermospheric effects on drag/debris
- Physics for Satellite Communications

Started @ EOARD
- Jul 2012

Started @ EOARD
- Oct 2012

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Space Technology Areas of Interest

• Vehicle Technologies
  – Novel mission concepts & non-traditional spacecraft configurations
  – High-precision sensor/actuator techniques; nanoelectronics fundamentals
  – Electric propulsion fundamentals; novel attitude determination & control techniques

• Astrodynamics
  – Orbit prediction/determination methodologies, orbit evolution uncertainty quantification
  – Space environment-spacecraft coupled nonlinear dynamics modeling techniques

• Remote Sensing/Imaging
  – Detection, tracking, identification, and object characterization methodologies
  – Adaptive/multi-modal sensing; multi-object tracking & estimation
  – Multi-sensor data fusion techniques; real-time signal processing

• Robotics/Autonomy
  – Autonomous guidance & control algorithms; path planning/trajectory optimization
  – Novel multi-agent/distributed coordination methodologies

• Responsive Space
  – Reconfigurable sensors
  – Modular/adaptive architecture methodologies
Current Projects

Germany
- Atmospheric Chemistry
- Electron Detachment Processes
- Faint Object Detection, SSA
- Electric Propulsion Instability

United Kingdom
- Space Debris Orbit/Attitude Prediction, SSA
- Droplet Sizing in Dense Sprays
- Printable Organic Nanoelectronics
- Multi-Object Estimation, SSA
- Dynamics of HAMR Objects, SSA
- Robust State Estimation, Controls
- Faint Object Detection, SSA

Belgium
- Non-equilibrium Plasma Modelling

France
- Rocket Engine Injector Modulation
- Electric Propulsion Instability
- LRE Ignition Prediction

Spain
- Magnetic Nozzles for Plasma Boiling & Slug Flow in Microgravity
- Hall Thruster Instabilities

Sweden
- Multiscale Methods
- Nonlinear Thermal Effects
- Plasma Interactions
- Applied Math

Russia
- Spacecraft Surface Optical Properties

Croatia
- Multi-Agent Distributed Control

Italy
- Spinodal Heat Transfer

Switzerland
- Space Obs Data Fusion, SSA

Blue = new for FY13

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EOARD Space Technology & Controls

Program objective: Exploit cutting-edge, international space S&T/R&D; identify, seed, and transfer world-class research in space vehicle technology, astrodynamics, and control sciences with emphasis on guidance, navigation, and control (GNC) for autonomous/intelligent systems, space situational awareness of objects, and remote sensing

- Space Debris Orbit and Attitude Prediction for Enhanced and Efficient SSA
  (Marek Ziebart, University College London, UK)
  - Novel model development for Nano-Satellite “sprites” for predicting space debris
  - Fills AF gap in enhanced methods of space object uncertainty quantification
  - DoD Space Policy 2012 calls for improved SSA including increased S&T investments and international collaboration

- Quantifying Space Environment Interactions with Debris Objects using Observation Data Fusion Techniques (Thomas Schildknecht, Astronomical Institute at the University of Bern, Switzerland)
  - Quantifies steady-state population of newly discovered near-GEO orbital debris
  - Provides AFRL highly-desired techniques for unique RSO identification, discrimination, and characterization

- Examination of Rotating Spoke Instability in a Cross-Field Discharge
  (Stephane Mazouffre, ICARE-CNRS, France)
  - 1st-Ever, world-leading Laser-Induced Fluorescent spectroscopy for high-speed optical diagnostics of plasma electric field in Hall Thrusters
  - Provides alternate electric propulsion technologies needed for AF to increase payload capability, increase mission lifetime, and reduce launch costs
  - Electric propulsion enables faster spacecraft repositioning (AF requirement) and offers new missions & special orbits

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Sun-to-Mud Coupling
State of the Science

**Solar Interior**
- MHD dynamics
- Emerging magnetic flux
- Backside imaging (helioseismology)

**Photosphere & Chromosphere**
- Mag. Field
- Solar Energetic Particles (SEPs)
- Flares / Coronal Mass Ejections (CME)
- Coronal holes / solar wind
- Radio Bursts
- X-ray/EUV emissions

**Heliosphere**
- Interplanetary Magnetic Field (IMF)
- Solar Wind
- Shocks/SEPs
- CMEs

**Magnetosphere**
- IMF
- Magnetic storms/substorms
- Auroral zones/ring currents
- Polar Cap Potential
- Radiation Belts
- South Atlantic Anomaly (SAA)

**Thermosphere & Ionosphere**
- Plasma bubbles / equatorial anomalies
- Scintillation / density fluctuation
- Neutral winds
- Travelling iono. disturbances
- UV Heating
- Ion chemistry
- Bulk ionosphere

Legend
- 6.1 – TRL 1-2
- 6.2 – TRL 3-4
- 6.3 – TRL 5-6

Driven/Compliant System

Persistent System
Program objective: Space science related to environmental aspects of space situational awareness (SSA) – Solar storm prediction/transport, Radiation and particle impacts, Ionospheric scintillation, Thermospheric effects on drag/debris, Physics for Satellite Communications

- **Flare Forecasting (Peter Gallagher, Trinity College, Dublin)**
  - Solar magnetic field is major source of energy which drives explosive events such as flares and coronal mass ejections (CMEs)
  - Research effort to automatically detect and characterize sunspot group magnetic and coronal evolutionary history on a large scale.
  - Understanding how energy/instabilities are built up in sunspot groups and identifying triggers will enable future flare forecasting systems.

- **Role of neutral atmospheric dynamics in cusp density (Anasuya Aruliah, University College London)**
  - Explain how the thermospheric density can be doubled over the cusp region (observed by CHAMP satellite but could not be modeled)
  - Dr. Herb Carlson (Utah State Univ) proposed that soft particle precipitation was the driver, which was contrary to “conventional wisdom” in research community
  - Used observations and modeling to verify the “Carlson effect” using the UCL Coupled Middle Atmosphere and Thermosphere model
Working with EOARD

• White papers and proposals through Program Officer
  – Email us for interest areas and timing
  – Accept all year, but Jun-Sep is ideal for next year planning

• Ideal white paper is 2 pages with...
  – Objective – 2-3 sentences of what you hope to accomplish
  – Summary of Approach – a few paragraphs explaining how you plan to accomplish your objectives
  – Impact – a paragraph or two explaining why the research is novel, how it will impact state of art, and why is it worth funding
  – References – a couple of most recent related publications (nice to include author’s proofs if available)
  – Estimated budget and duration
    • Break out rough budget by labor (PI, post-doc, students?), materials/supplied, facilities/equipment, misc expenses, travel, and indirect overhead

• Funding decision and grant can be very fast to slow depending on current availability of funds and PO and other DoD interest
Summary

• **EOARD**: Linking leading international researchers to Air Force basic research needs and opportunities
  – Broad range of interests in innovative/selective research
  – Actively coupled to AFOSR and other AFRL programs
  – Long history of funding leading European research
  – Looking for new ideas and eager partners

• Submissions & more information:
  
  Lt Col Kevin Bollino  
  AFOSR/IOE (EOARD)  
  kevin.bollino@us.af.mil  
  +44 (0)1895-616163

  [http://tinyurl.com/afosr-eoard](http://tinyurl.com/afosr-eoard)
EOARD Programs of Relevance

**Space Technology & Control Sciences**
- Lt Col (Dr) Kevin Bollino, kevin.bollino@us.af.mil
- Space vehicle technologies, astrodynamics, remote sensing/imaging, robotics/autonomy, responsive space

**Space Sciences**
- Dr Tom Caudill, tom.caudill@us.af.mil
- Space weather, plasma physics, RF/communications, remote sensing

**Lasers & Electro-Optical (EO)**
- Dr John Gonglewski, john.gonglewski@us.af.mil
- Novel lasers, some work with on-chip photonic electronics

**Math & Ops Research**
- Maj (Dr) Jeremy Jordan, jeremy.jordan@us.af.mil
- Multi-disciplinary optimization, applied mathematics that support higher-order computational methods

**Information Sciences**
- Dr Jamie Lawton, james.lawton@us.af.mil
- Planning & scheduling software, quantum information processing
EOARD Programs of Relevance (Cont.)

**MATERIALS & NANOTECHNOLOGY**
- Lt Col (Dr) ‘Ty’ Pollak, randall.pollak@us.af.mil
- Structural/functional materials, modeling, novel manufacturing

**ADVANCED AEROSPACE STRUCTURES**
- Maj (Dr) Matt Snyder, matthew.snyder.2@us.af.mil
- Structural dynamics, structures for extreme environments, computational methods, health monitoring

**AERONAUTICAL SCIENCES**
- Dr Gregg Abate, gregg.abate@us.af.mil
- Some work in bio-autonomy and adaptive systems

**PHYSICS**
- Lt Col (Dr) Vic Putz, victor.putz@us.af.mil
- Some work in nanoelectronics, electromagnetics, and quantum information
Program objective: Provide World Class Awareness, Strategy, and Science R&D in Directed Energy, High-Powered Microwaves, Coherent Sources, Optical Materials, Detectors, and Photonics

• Program 1: High-Energy Fiber Lasers (Dr. J. Nilsson, Southampton Optoelectronics Research Center, UK)
  – High-Energy Fibers have unprecedented performance in thermal control, quality of beam, and efficiency for DEW applications
  – Increased science understanding leads to improved system performance

• Program 2: High-Powered Microwave Metamaterials (Dr. R. Seviour, Lund University, Sweden)
  – HPM metamaterial sources promise order of magnitude compactness and power over conventional sources
  – Revolutionary control over Electro-magnetic waves give new regimes of applications to space and air flight

• Program 3: Terahertz Sources for Nondestructive Inspection and Communications (Dr. M. Ebrahim, Optics Research Center, Spain)
  – Terahertz is last unexploited band in the Electro-magnetic spectrum
  – Unprecedented ability to image through composites and paint for aircraft structure inspection
  – Science needed for ultra-wideband Comm and robotic vision
Program objective: Exploit modern developments in physics for information processing/superiority, new electronic capabilities, and control of electromagnetic radiation.

• **Quantum Information Systems (Ian Walmsley, Oxford)**
  – Could lead to first demonstration of quantum system outperforming conventional computing.
  – Developing infrastructure for further photonic systems
  – Excellent tech transfer—lead researcher is a USAFA faculty pipeline student

• **Graphene-based Heterostructures (Andre Geim, Manchester)**
  – Possible replacement for silicon transistors in electronics industry
  – Exploration of combinations of materials for novel physics applications

• **Metamaterials (John Pendry, Imperial College London)**
  – Control of EM radiation: cloaking, perfect lenses et al
  – Current theoretical work: “Transformation Optics”, topological study of families of EM structures
Program objective: Emerging physics, chemistry, materials science, mechanics, and mathematics to enable **NEW CLASSES OF MATERIALS**

**Emphasis areas:** Materials modeling, novel fabrication, nanomaterials synthesis, and 3D materials characterization

• **Magnetic assembly of heterogeneous bio-inspired composites**
  (Prof. Dr. André Studart, ETH Zurich, Switzerland)
  – Natural materials (shell, bone, tendon...) are extremely tough despite inferior constituents due to hierarchical design & precise orientations
  – State-of-the-art additive layer techniques are today inadequate for complex bio-inspired microstructures for very high performance
  – Micro-reinforcement coated w/ superparamagnetic micro-/nanoparticles enables precise microstructural control under very low magnetic fields

• **Towards truly monodisperse cluster-assembled materials**
  (Prof. Dr. Ulrich Heiz, TU Munich, Germany)
  – Precise atomic-scale control of nanoparticle morphology & distribution can dramatically improve catalyst performance for energy applications
  – Structure & reactivity of nanoclusters “soft landed” on moiré patterned graphene is under study at highest spatial and temporal resolutions

• **Dendritic nanoparticles as self-assembled building blocks**
  (Dr. Donnio & Dr. Gallani, CNRS/IPCMS Strasbourg, France)
  – Metal nanoparticles functionalized w/ dendritic ligands using click-chemistry techniques offer new “building blocks” for functional materials
  – Comprehensive study to synthesize & characterize various symmetries for columnar/lamellar/cubic phases and electrically control properties
Program objective: Find, fund and transition international basic science research in the field of aerospace structures with direct application to the USAF.

Keywords: hypersonic structures, aeroelasticity and reconfigurability, computational modeling, novel composite structures

• Multi-Scale Understanding of Thermoacoustic Fatigue in Aerospace Structures (Eann Patterson, University of Liverpool, UK)
  – Develop methodology and produce validation quality data to measure strain/stress fields during thermoacoustic fatigue loading
  – Enabler for Air Force vision of reusable, hypersonic flight capable vehicles

• Novel Heterogeneous Multi-Axial High Strain Rate Tests of Materials (Fabrice Pierron, University of Southampton, UK)
  – Design and test specimens at high strain rates. Measure strain and acceleration maps using digital image correlation
  – Support design and development of survivable weapons systems
  – Drive towards in situ characterization of materials in their required geometries

• Variable Stiffness Wing Structures with Compliance for Aeroelastic Morphing (Paolo Ermanni, ETH Zurich, Switzerland)
  – Exploit controlled buckling of variable stiffness components to provide passive airfoil shape change – aerodynamic force provides the triggering mechanism
  – Reduce aircraft weight and increase aerodynamic efficiency
EOARD Aero Sciences Highlights

Program objective: Fundamental research which helps elucidate critical knowledge and understanding Aerodynamics, Bio-Inspired Autonomy, Advanced Air Vehicle Sciences, and Air-Breathing Propulsion

• Flow Control for Supersonic Inlets (Prof. H. Babinsky, Cambridge University, UK)
  – Vortex generators have been shown to reduce unsteadiness and increase pressure recovery in supersonic inlets
  – Offers improved performance for air-breathing engines in supersonic inflow

• Attack Strategies in Birds of Prey (Prof. G. Taylor, Oxford University, UK)
  – To determine the guidance and control strategy(ies) that are used by birds of prey to intercept aerial and terrestrial targets
  – Influence the development of small, agile, autonomous vehicles whose capabilities include identifying and intercepting moving targets
  – First quantitative insight into the guidance strategies used by birds of prey in flight

• Real-time wing-vortex-pressure distribution in unsteady flight conditions (Prof. P Masarati, Politecnico di Milano, Italy)
  – Develop the capability to estimate aerodynamic loads and vorticity on extremely flexible air vehicles in unsteady flight
  – Exploit highly compliant airframes for increased efficiency and agility
Program objective: International Research in C4ISR and Information Technologies, with an emphasis on C2 Planning & Scheduling and Software & Systems Research

Cyber Security: “Universal Batch Steganalysis”
- Dr Tomas Pevny, Czech Technical University
- Andrew Ker, Oxford University
- Construct a universal steganalyzer capable of simultaneously analyzing multiple objects from multiple sources, by using state-of-the-art clustering techniques

C2 Planning: “Adaptive Problem Solving by Analogy”
- Prof Georgi Petkov, New Bulgarian University
- Analogies for Planning: Explore how certain cognitive mechanisms can be modeled within the DUAL cognitive architecture and how they would enhance its ability to do problem-solving by analogy

Software & Systems: “Software Regression Verification”
- Prof Ofer Strichman, Technion University, Israel
- Formal methodology for conducting automated or semi-automated software regression testing
- Develop notions of equivalence and corresponding proof rules

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 EOARD Operations Research and Mathematics Highlights

Program objective: Advance Operations Research and mathematical research to give the Air Force analyst innovative theoretical methods for modeling and analysis of AF problems

Emphasis Areas: Optimization, Human Behavior Modeling, Decision Making, Statistical Modeling, and Simulation

• Quantum Probability for Human Behavior Modeling (Emmanuel Pothos, City University)
  - DoD needs to understand & model human behavior more accurately
  - QP allows modeling of irrationality (departures from CP) in human decisions

• Optimization over the Nondominated Set of a Multiobjective Optimization Problem (Matthias Ehrgott, Lancaster University)
  - Currently use inefficient global optimization methods to generate efficient frontier
  - Exploit the structure of the MO optimization problem to develop faster algorithms
  - Decompose MO linear program to extend algorithms to general MO program

• Mathematical Programming for Optimal Network Design Problems (Athanasios Migdalas, Aristotle Univ of Thessaloniki)
  - Visiting professorship to the REEF Mathematical Modeling and Optimization Institute – AFOSR and AFRL/RW partnership institute support
  - Optimally plan order of operations in a network design/re-design problem
  - Research optimal planning for communication, computer, & sensor networks