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AIR FORCE STTR 17.C Topic Descriptions

AF17-CT01 TITLE: Sun-Tracking Millimeter Wave Radiometer

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct ITAR specific questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Design and implement a sun-tracking radiometer system to measure millimeter wave attenuation with high dynamic range and temporal resolution. Threshold values are 30 dB dynamic range and 5 second resolution.

DESCRIPTION: Development of new satellite communications capabilities in the allocated V and W frequency bands of 71-76 GHz and 81-86 GHz require the measurement of the atmospheric attenuation characteristics at these frequencies. This includes measurement of the fade dynamics and attenuation statistics. There is a dearth of relevant data at millimeter wave frequencies available to test or develop predictive models and fade mitigation techniques. The usual approach to collecting attenuation data utilizes beacons from satellites in geo-stationary orbits, which is expensive and can take many years to implement. On the other hand, the quiet sun is a source of millimeter waves that can be exploited to provide much needed data at a low cost and flexibility in site location.

Sun-tracking techniques employing radiometers to measure atmospheric attenuation were developed and utilized by a few researchers in the 1960s and 1970s. However, there has been little if any use of the sun-tracking approach since and there is currently little familiarity with this technique. Radiometer systems have improved significantly in recent years, but there are no commercially available systems designed to provide sun-tracking measurements. Recently the radiometric sun-tracking technique has been re-introduced (see refs 3-5). But those measurements were made with a modification of a commercial radiometer and not optimized for sun-tracking measurements.

The topic seeks the design and implementation of a stand-alone sun-tracking based system that can measure millimeter wave attenuation over a dynamic range greater than 30 dB with a 3 second minimum temporal resolution. The system should be capable of measuring at least two frequencies simultaneously (nominally 73 and 83 GHz) under most atmospheric and weather conditions including rain and snow. The system should include all sensors (such as meteorological instruments) and algorithms needed for stand-alone operation. It should be designed to operate over a broad range of elevation angles; from at least 10° to 90°. The sensor should be designed to operate with minimal direct operator control.

These radiometer systems will provide key data needed to define V and W band satellite communication system architectures. Multiple units will be required to collect the attenuation characteristics at a variety of geographic locations.

While this topic addresses specific frequencies, the sun-tracking radiometer system may be easily adapted for use with other frequencies of interest. It would for example be useful in the commercial development of Q and V band (40 and 50 GHz) satellite communication systems for which there is growing interest but little data. This type of measurement system can be utilized as a research tool for radio astronomy to provide valuable sun brightness temperature estimates which is almost unexplored beyond Ku band.

PHASE I: The Phase I effort will conduct analysis to determine the an optimal design sensing strategy and expected performance. Critical engineering challenges will be identified.

PHASE II: The Phase II effort should demonstrate the expected system performance. It should build and deliver a complete prototype system.

PHASE III DUAL USE APPLICATIONS: Commercialize production based on Phase II prototype to provide additional features and capabilities of general interest. Produce a multitude of units in order to perform measurements at a variety of geographic locations.

REFERENCES:

1. Croom D. (1973), “Sun as a broadband source for tropospheric attenuation measurements at millimetre wavelengths”, Proc. IEE, vol 120, 1200-1206.

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3. Mattioli V., F.S. Marzano, A.V. Bosisio, G.A. Brost, K.M. Magde, “High-frequency prediction of rain attenuation from ground-based microwave radiometric measurements through a sun-tracking technique”, 14th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment (MicroRad), Espoo (Finland), April 11-14, 2016.

4. Marzano F.S., L. Milani, V. Mattioli, K. Magde, G. Brost, “Retrieval of precipitation extinction using ground-based Sun-tracking millimeter-wave radiometry”, IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Beijing (China), July 10-15, 2016.

5. Brost, G and K.M. Magde, “On the Use of the Radiometer Formula for Atmospheric Attenuation Measurements At GHz Frequencies”, European Conference on Antennas and Propagation (EuCAP), Davos, April 11-14, 2016.

KEYWORDS: Sun-tracking, radiometer, propagation

TPOC-1: George Brost
Phone: 315-330-7669
Email: george.brost@us.af.mil

AF17-CT02 TITLE: Rapid Discovery of Evasive Satellite Behaviors

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct ITAR specific questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop robust, near real-time algorithms that rapidly discover the behavioral patterns and operational intent of potentially evasive and/or ambiguous active resident space objects (RSOs) for the purposes of space situational awareness (SSA) across the entire SSA space catalog.

DESCRIPTION: Space protection and SSA require rapid and accurate space object behavioral and operational intent discovery. Ground- and space-based Air Force surveillance assets are a critical foundation of U.S. space control operations. Optimally and autonomously controlling their actions effectively and in real-time is fundamental to space object evasive and ambiguous behavioral pattern identification.

The problem of behaviorally evasive intent identification is challenging for several reasons. For example, surveillance assets do not completely observe all RSO variables, and system and subsystem parameters required to infer intent. RSOs can potentially be reactive, continuously responding to their perceived environment and choosing their actions correspondingly in order to evade discovery of their capabilities. The problem is further complicated by the fact that the process of intent and capability discovery is fraught with uncertainty in the underlying behavioral pattern models and RSO states, in the observation process, and in the behavioral policy pursued by the RSO. Finally, it is also desired to select a set of surveillance actions that maximize the likelihood of behavioral and capability identification. Due to the large number of hypothetical actions, counter-actions and counter-counter-actions made by the surveillance asset and the RSO over a future look-ahead window of time, along with the large number of RSOs in the space catalog, the problem of optimizing the surveillance asset's actions over the look-ahead period is computationally intractable. Given a surveillance asset's capabilities, the ability to identify the existence of undiscoverable RSO "blind-spot" behaviors is critical.

Advanced algorithms to process a diverse set of raw sensor data and optimal action selection under uncertainty for enhanced behavioral intent and capabilities discovery are needed. Such algorithms must be highly responsive and adaptive despite the curse of dimensionality that underlies the optimal operational intent identification problem. Existing and new reliable RSO probabilistic patterns of behavioral models need to be utilized. Such models describe the set of possible states an RSO may assume and how these states can transition from one to the other given a surveillance asset's chosen action. An appropriate utility function for the optimal surveillance policy needs to be developed. Such a function should be designed in order to discover an RSO's intent, if possible, in the shortest amount of time with the highest level of confidence level given the uncertainty underlying the problem.

This topic solicitation addresses the problem of behavioral intent and operational capability discovery within an uncertain game theoretic context, with an interest in improved optimal surveillance asset action selection for rapid identification. Innovative solutions are sought for efficient and rapid discovery despite behavior model uncertainty and RSO action strategy under potentially large number of evasive strategies. Algorithms that are capable of processing raw observation data along with intelligence data and environmental data will be of particular interest.

PHASE I: Develop the mathematical basis for dynamic behavior models to enable near real-time behavioral patterns and operational intent identification. Develop algorithms that compute surveillance asset optimal policies under modeling uncertainty. Identify techniques to detect technological gaps in identifying intent under evasive and/or ambiguous active RSO behavior. Provide a prototype demonstration as applied to a few RSOs in the catalog.

PHASE II: Provide a scalable prototype demonstration of the technology in a realistic environment using realistic data with errors and biases as well as realistic processing speeds in complex scenarios. Extend algorithms to accommodate different sensor designs and sensing environments. Demonstrate scalability with respect to behavioral patterns model parameter space, as well as with respect to the number of RSOs. The solution must be demonstrably scalable over the number of RSOs in a representative SSA space catalog.

PHASE III DUAL USE APPLICATIONS: Rapid evasive intent and behavioral identification under uncertainty is highly applicable to many military (Joint Space Operations Center), civilian and public safety and security uses.

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1. Kaelbling, L.P., Littman, M.L., Cassandra, A.R. "Planning and acting in partially observable stochastic domains". Artificial Intelligence Journal, Vol. 101: pp. 99–134, 1998.

2. Mertens, J. F. & Neyman, A. "Stochastic Games". International Journal of Game Theory Vol. 10, No. 2, pp. 53–66, 1981.

3. Neyman, A. & Sorin, S. "Stochastic Games and Applications". Dordrecht: Kluwer Academic Press, 2003.

KEYWORDS: Satellite characterization, behavior modeling, dynamic behavior models, sensor optimization

TPOC-1: Carolyn Sheaff
Phone: 315-330-3038

Email: carolyn.sheaff@us.af.mil

AF17-CT03 TITLE: Operational Outer Zone Energetic Charged Particle Model

TECHNOLOGY AREA(S): Space Platforms

OBJECTIVE: Develop a model of the outer zone of Earth's radiation belt that is suitable for operational specification of electron flux levels.

DESCRIPTION: The outer zone of Earth's radiation belt can be defined as locations in the magnetosphere where the geomagnetic L parameter is greater than 3, corresponding to altitudes of hundreds of kilometers (inclined Low Earth Orbits) to over 35,000 kilometers (Geostationary Orbit and beyond). This zone contains a highly variable population of electrons at relativistic energies (corresponding to greater than 500 kiloelectron-volts) that can be hazardous to spacecraft. The Secretary of the Air Force has mandated pre-Milestone B satellite programs as of March 2015 incorporate an Energetic Charged Particle (ECP) sensor to support space hazard assessment and space situational awareness. In order to accelerate the deployment of this capability, models allowing accurate estimates of energetic charged particle flux will aid in providing complete coverage, and couple with efforts to deploy hosted ECP sensors on commercial platforms.

The outer zone population is dynamic and driven, influenced by changes in the electromagnetic field at many length- and time-scales [1]. Recent simulation efforts largely focus on capturing one or more aspects of this system with a combination of physical modeling and data assimilation. This has largely been limited by a lack of suitable data sources that cover the spatial region of interest.

The recent release of electron flux data from the GPS fleet could be transformative to data assimilative modeling efforts [2]. The extensive spatiotemporal coverage of these data (over a decade of data from 6 MEO orbit planes with 6 satellites each) can greatly enhance the training and execution of models that can ingest it. This is true for a variety of modeling approaches: machine learning, empirical or applying a Kalman filter to a physical model [3, 4]. Regardless of technical approach employed, the resulting model should capture the dynamic and driven nature of the outer zone electrons as reflected in flux levels at specified energy ranges, informed by ECP sensor requirements.

PHASE I: Prototype model and source code, scientific validation, and roadmap to development required for operational deployment.

PHASE II: Prototype model and source code demonstrating needed operational capabilities suitable for V&V, documentation, and test suite.

PHASE III DUAL USE APPLICATIONS: Model suitable for use by military, civil, and commercial space organizations.

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3. Reeves, G. D., Y. Chen, G. S. Cunningham, R. W. H. Friedel, M. G. Henderson, V. K. Jordanova, J. Koller, S. K. Morley, M. F. Thomsen, and S. Zaharia (2012), Dynamic Radiation Environment Assimilation Model: DREAM, Space Weather, 10, S03006, doi:10.1029/2011SW000729.

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KEYWORDS: Van Allen, Radiation Belt, Space Environment, Modeling, Physics, Data Assimilation

TPOC-1: James McCollough
Phone: 505-846-3197
Email: james.mccollough@us.af.mil

AF17-CT04 TITLE: Design of III-V Antimonide InAs/InAsSb Strained-Layer Superlattice Materials for Improved LWIR Performance

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop minority carrier transport model software based on innovative electronic structure and transport models leading to superior nBn InAs/InAsSb antimonide-based strained-layer superlattice materials.

DESCRIPTION: For III-V infrared focal plane arrays for mid-wavelength infrared (MWIR) and long wavelength infrared (LWIR) imaging, InAs/InAsSb strained-layer superlattice materials using unipolar barrier device structures are a promising technology. The use of such superlattices increases the minority carrier lifetime dramatically over Ga-containing antimonide materials to be comparable with HgCdTe but also introduces numerous barriers to minority carrier transport. These barriers disrupt carrier transport, either intrinsically or through the introduction of additional roughness to the barriers. To this point, modern high-accuracy transport calculations do not utilize the electronic structure of the full superlattice material.

PHASE I: Develop a model that can integrate the superlattice electronic structure calculations used for optical absorption, Auger recombination, defect scattering, and other design criteria, with an accurate transport calculation suitable for operating temperatures and doping ranges of interest for such detectors. Deliver initial prototype model and software code for scientific validation.

PHASE II: Develop the model into a prototype software product that can be reliably used with limited expertise. Demonstrate use of the software to predict vertical transport carrier mobilities and, when combined with carrier lifetime calculations, to predict quantum efficiencies and detectivities. Deliver prototype model software for verification with experimental results.

PHASE III DUAL USE APPLICATIONS: Further develop the software product to be generic for any III-V material superlattice design, making it widely applicable for commercial and defense emitter and detector applications in any wavelength range.

REFERENCES:
1. E. H. Steenbergen, B. C. Connelly, G. D. Metcalfe, H. Shen, M. Wraback, D. Lubyshev, J. M. Fastenau, A. W. K. Liu, S. Elhamri, O. O. Cellek, and Y.-H. Zhang, Appl. Phys. Lett. 99, 251110 (2011).

2. B. V. Olson, L. M. Murray, J. P. Prineas, M. E. Flatte, J. T. Olesberg, and T. F. Boggess, Appl. Phys. Lett. 102, 202101 (2013).

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KEYWORDS: infrared, superlattice, detector, transport, model, software

TPOC-1: Elizabeth Steenbergen
Phone: 505-853-2680
Email: elizabeth.steenbergen.1@us.af.mil

AF17-CT05 TITLE: Verification and Validation of Algorithms for Resilient Complex Software Controlled Systems

TECHNOLOGY AREA(S): Space Platforms

OBJECTIVE: This STTR topic will investigate approaches to verification and validation (V&V) of algorithms for GN&C of spacecraft without on-orbit testing.

DESCRIPTION: As potentially one of the most sensitive subsystems within the flight software to subtle disruptions that are difficult to detect and prevent, the need for resilient, cyber-hardened software architectures for GN&C (guidance, navigation, and control) of spacecraft is significant and the capability to V&V the systems before deployment is necessary. Currently, V&V of spacecraft GN&C systems must be accomplished through on-orbit testing. Selected proposers will be provided a problem of interest both to the Air Force as well as to all national security space systems on which to apply their V&V algorithms. Potential approaches are provided in the references, but the proposer is encouraged to consider alternative approaches as well.

PHASE I: Final Report with simulated approaches to algorithms on spacecraft GN&C problems plus algorithms & simulations in MATLAB code.

PHASE II: Matlab Simulink code suitable for auto-generation of Real-Time ANSI C/C++ flight code of algorithms (using Simulink Coder), additional Matlab code used in high-fidelity simulations and regression testing of algorithms, and a Final Report.

PHASE III DUAL USE APPLICATIONS: Demonstration of developed flight code in a hardware testbed environment plus a Final Report.

REFERENCES:
1. Johnson, T. T., Green, J., Mitra, S., Dudley, R., and Erwin, R. S.," Satellite Rendezvous and Conjunction Avoidance: Case Studies in Verification of Nonlinear Hybrid Systems," Proc. 18th International Symposium on Formal Methods, pp. 252-266, Paris, France, August 2012.

2. Frey, G. and Litz, L., "Verification and Validation of Control Algorithms by Coupling of Interpreted Petri Nets," Proc. IEEE International Conference on Systems, Man, and Cybernetics (ICSMC), 1998; doi: 10.1109/ICSMC.1998.725375.

3. Liu, Shaoying, "Testing-Based Formal Verification for Algorithmic Function Theorems and Its Application to Software Verification and Validation," Proc. 2016 International Symposium on System and Software Reliability (ISSSR), 2016; doi: 10.1109/ISSSR.2016.010.

KEYWORDS: verification, validation, algorithms, controls

TPOC-1: Morgan Baldwin
Phone: 505-846-9600
Email: morgan.baldwin@us.af.mil