DEFENSE THREAT REDUCTION AGENCY
SBIR FY10.3 Proposal Submission

The mission of the Defense Threat Reduction Agency (DTRA) is to safeguard the United States and its allies from weapons of mass destruction (WMD)—chemical, biological, radiological, nuclear and high-yield explosives—by providing capabilities to reduce, eliminate and counter the threat and mitigate its effects. This mission includes research and development activities organized into chemical/biological, nuclear, counter WMD, and innovation/systems engineering technology portfolios. From these activities, DTRA administers two SBIR programs. One is affiliated with the Chemical-Biological Defense Program and appears as a separate component when participating in a solicitation. The other is drawn from the nuclear, counter WMD, and innovation/systems engineering portfolios and is described herein. Communications for this program should be directed to:

Defense Threat Reduction Agency
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Use of e-mail is encouraged.

The DTRA SBIR program complements the agency's principal technology programs to detect/locate/track WMD; interdict or neutralize adversary WMD capabilities; protect against and restore following WMD use; attribute parties responsible for WMD attacks; and provide situational awareness and decision support to key leaders. SBIR topics reflect the current strategic priorities where small businesses are believed to have capabilities to address challenging technical issues. DTRA supports efforts to advance manufacturing technology through SBIR, where the challenges of such technology are inherent to technical issues of interest to the agency.

PROPOSAL PREPARATION AND SUBMISSION

Proposals (consisting of coversheets, technical proposal, cost proposal, and company commercialization report) will be accepted only by electronic submission at http://www.dodsbir.net/submission/. Paragraph 3.0 of the solicitation (found at http://www.dodsbir.net/solicitation/) provides the proposal preparation instructions. Consideration is limited to those proposals which do not exceed $150,000 and seven months of performance. The period of performance may be extended up to five additional months following award, but such extensions may delay consideration for Phase II proposal invitation. Proposals may define and address a subset of the overall topic scope. Proposals applicable to more than one DTRA topic must be submitted under each topic.

PROPOSAL REVIEW

During the proposal review process, employees from BRTRC, Inc., and TASC, Inc., will provide administrative support for proposal handling and will have access to proposal information on an administrative basis only. Organizational conflict of interest provisions apply to these entities and their contracts include specifications for non-disclosure of proprietary information. All proposers to DTRA topics consent to the disclosure of their information to BRTRC and TASC employees under these conditions.

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DTRA will evaluate Phase I proposals using the criteria specified in paragraph 4.2 of the solicitation with technical merit being most important, followed by principal investigator qualifications, and commercialization potential. Topic Points of Contact (TPOC) lead the evaluation of all proposals submitted in their topics.

SELECTION DECISION AND NOTIFICATION

DTRA has a single source selection authority (SSA) for all proposals received under one solicitation. The SSA either selects or rejects Phase I proposals based upon the strengths and weaknesses identified in proposal review plus other considerations including limitation of funds and balanced investment across all the DTRA topics in the solicitation. Balanced investment includes the degree to which offers support a manufacturing technology challenge. To balance investment across topics, a lower rated proposal in one topic could be selected over a higher rated proposal in a different topic. DTRA reserves the right to select all, some, or none of the proposals in a particular topic.

Following the SSA decision, the contracting officer will release notification e-mails through DTRA's SBIR evaluation system for each accepted or rejected offer. E-mails will be sent to the addresses provided for the Principal Investigator and Corporate Official. Offerors may request a debriefing of the evaluation of their proposal. Once released, debriefings are viewable at https:\\www.dtrasbir.net\debriefing\ and require password access. Debriefings are provided to help improve the offeror's potential response to future solicitations.

For selected offers, DTRA will initiate contracting actions which, if successfully completed, will result in contract award. DTRA Phase I awards are issued as fixed-price purchase orders with a seven-month period of performance that may be extended, as previously discussed. DTRA may complete Phase I awards without additional negotiations by the Contracting Officer or opportunity for revision for proposals that are reasonable and complete.

DTRA's projected funding levels support a steady state of 18 Phase I awards annually over multiple solicitations. Actual number of awards may vary.

DTRA Phase I awards for this solicitation will be fully funded with FY11 appropriation available on or after January 1, 2011. Awards will be subject to availability of those funds and are expected to occur by the end of March 2011.

CONTINUATION TO PHASE II

Only Phase II proposals provided in response to a written invitation from a DTRA contracting officer will be evaluated; no unsolicited proposals will be accepted. DTRA invitations are issued based on the degree to which the offeror successfully proved feasibility of the concept in Phase I, program balance, and possible duplication of other research. Phase II invitations are issued when the majority of Phase I contracts from the preceding solicitation are complete. Phase I efforts which were delayed in award or extended after award will be considered for invitation the following year. DTRA is not responsible for any money expended by the proposer prior to contract award.

DTRA's projected funding levels support a steady state of 5-7 new Phase II awards annually, continuing approximately 33 percent of Phase I efforts to Phase II. Actual number of awards may vary.

OTHER CONSIDERATIONS

DTRA does not utilize a Phase II Enhancement process. While funds have not specifically been set aside for bridge funding between Phase I and Phase II, DTRA does not preclude FAST TRACK Phase II awards, and the potential offeror is advised to read carefully the conditions set out in this solicitation.

Notice of award will appear first on the Agency Web site at http://www.dtra.mil. Unsuccessful offerors may receive debriefing upon written request only. E-mail correspondence is considered to be written correspondence for this purpose and is encouraged.

DTRA SBIR 10.3 Topic Index

DTRA SBIR 10.3 Topic Descriptions

DTRA103-001 TITLE: Calculation of Impulse Response Function During Realistic Scenarios

TECHNOLOGY AREAS: Battlespace, Nuclear Technology

OBJECTIVE: Develop a software simulation that provides numerical realizations of the impulse response function and the transfer function that describe the transionospheric propagation of wide bandwidth electromagnetic (EM) signals in realistic scenarios. This simulation should apply to the case of multiple, spaced equatorial plasma bubbles and to multiple high altitude nuclear bursts. The instantaneous statistics of the propagation channel should be allowed to vary as the line of sight moves in the simulated scenario. The simulation should incorporate a direct solution of the problem of EM propagation and correctly model both weak and strong scattering channels. Both mean effects due to smooth ionization and scintillation effects due to ionospheric structure should be included.

DESCRIPTION: The DTRA channel impulse response function (CIRF) family of codes generates numerical realizations of the impulse response functions of EM signals that propagate through the nuclear or naturally disturbed ionosphere. These functions allow developers of satellite communications equipment and radar systems that have a requirement to operate through propagation disturbances to test their signal processing designs against various levels of scintillation. Such testing allows equipment suppliers to compare design options in scintillation and helps to assure that the equipment is sufficiently hardened against propagation disturbances.

However, the actual propagation environment changes with time in a manner determined by the physics of the ionosphere and the physics of the nuclear detonation. In the natural equatorial ionosphere, the equatorial electrojet carries the structure from west to east after bubble formation. With time the strength of the irregularities decreases and spectrum of the structure changes as small scale sizes become less important. In a nuclear detonation the physics of the structure evolution is less well understood, but at some point after the burst time, the evolution of the structure is controlled by the same processes present in the natural ionosphere. Thus testing using the CIRF codes fails to fully establish system performance under time varying propagation conditions.

This project is intended to develop the next generation high fidelity EM propagation code to generate temporally and spatially varying channel impulse response functions. For this work, the EM propagation simulation should accept as inputs a physical description of the propagation environment, including but not limited to the following: the transmitter and receiver (SATCOM) or radar and target location (RADAR), and the transmission frequency and bandwidth of the propagating EM signal. For the natural equatorial ionosphere, the inputs include the bubble location, bubble size, mean electron density, PSD of the electron density fluctuations, and the specification of the spatial and temporal evolution of the electron density fluctuations. For nuclear bursts, inputs include the burst yields and locations and a description of the in-situ ionization in time and space. The inputs are intended to provide the physical description of the ionospheric ionization density over the spatial and temporal extent of interest in the EM propagation problem.

The goal of this project is to produce a realistic EM propagation simulation of the impulse response function based directly on the physics of the propagation environment without use of intermediate codes to statistically describe the characteristics of the propagation channel.

PHASE I: Develop the proposed methodology in sufficient mathematical detail to show technical competency. Phase I should also clearly demonstrate the development and use of code to model temporal and spatial evolution for the case of a two-dimensional propagation geometry where the EM signal propagates in the direction perpendicular to infinitely elongated striations (as would occur in the equatorial regions).

PHASE II: Develop a prototype three-dimensional EM propagation code and compare the results to experimental data obtained from various ionospheric measurements. Because of the strategic importance of long-range radar, numerical examples should be developed to document the use of the generated CIRF to calculate realizations of the output of a detector for a transmitted linear FM pulse. Phase II should also include a preliminary user manual and graphical user interface. An important aspect of this phase is to develop a detailed plan for commercializing the prototype for use by the government and private sector.

PHASE III: A Phase III project would develop a commercial version of the Phase II code on a fast running computer based on single or multiple central processing units. Potential users include contractors that support the possible US Space Based Radar program who are interested in detailed modeling of the propagation of wide bandwidth signals at VHF-through L-band. The ionosphere is known to be important for wideband propagation of signals intended for foliage penetration. A Phase III project would develop a commercial version of the Phase II prototype code to include user friendly graphical user interface for licensing with software releases, user manuals and completed examples.

PHASE III DUAL USE APPLICATIONS: Developers of civilian satellite communications system would also benefit from the ability to predict channel impulse response functions with a time-varying line-of-sight.

REFERENCES:
1. D. L. Knepp, "Multiple Phase-Screen Calculation of the Temporal Behavior of Stochastic Waves," Proceedings of the IEEE, Vol. 71, No. 6, pp. 722-737, June 1983.

2. D. L. Knepp and L. A. Wittwer "Simulation of Wide Bandwidth Signals That Have Propagated Through Random Media," Radio Science, Vol. 19, No. 1, pp. 303-318, January-February 1984.

3. R. A. Dana, ACIRF User's Guide for the General Model (Version 3.5), DNA-TR-91-162, June 1992.

KEYWORDS: scintillation, striations, signal propagation, radar, satellite communications, simulation, ionosphere

DTRA103-002 TITLE: Innovative Computational Mitigation of Radiation Effects in Nano-technology Microelectronics

TECHNOLOGY AREAS: Sensors, Electronics, Nuclear Technology

OBJECTIVE: The successful outcome of this effort will support the use of ultra-deep submicron integrated circuits in satellite systems that will result in very significant savings in weight, power and reliability for systems that include Space Radar, Space Tracking and Surveillance Systems and others. In addition, this effort will also support the use of compound semiconductor technologies (e.g. III-V based devices: antimony compound semiconductors, indium phosphate, and others) in these systems and their introduction into advanced spacecraft and missile systems with similar savings in both power and weight, coupled with increased performance.

DESCRIPTION: Current satellite systems are fabricated using a mix of commercial and radiation hardened circuits. However, the use of advanced commercial integrated circuits devices results in added complexity to mitigate radiation effects that can result in the miss-operation and/or destruction of devices. In many cases, the penalties in increased power, area, weight and added circuit complexity out-weigh any potential benefits and preclude the use of the advanced commercial technology. Moreover, these technologies have demonstrated sensitivity to radiation effects.

The current methods to mitigate radiation effects, while proven to be effective at circuit geometries > 150 nm silicon based technology, have been shown to be less effective when applied to integrated circuit feature sizes below 100 nm silicon based and compound semiconductor technologies. In addition, the introduction of new technologies, e.g. quantum function circuits, will require the development of new mitigation approaches. Thus, if minimally invasive methods such as the use of alternative materials, circuit enhancements, and other innovative approaches could be developed to reduce radiation effects sensitivity these devices could be used with little or no penalties. Therefore, the basic approach to accomplish this task would be to leverage commercial microelectronics at the < 90 nm nodes and augment these technologies with radiation mitigation techniques that would have minimal impact on the electrical performance and manufacturability. This same approach also applies to the radiation hardening of the compound semiconductor and other technologies.

Additionally, the development of such methods requires the development of cost effective methods to model and simulate the radiation response of these < 90 nm, compound semiconductor and other technologies. Without a robust modeling and simulation capability it would be both technically and economically unfeasible to develop these mitigation methods.

PHASE I: Identify innovative computational methods, novel algorithms and Boolean operations, which does not involve triple modular redundancy (TMR) or special transistor structures (i.e. no change to the I-V curves), to mitigate radiation effects in 90 nm microelectronics technologies, III-V, SiGe, SiC and other materials systems. Identify innovative conversion methodology from one foundry to another and/or from one feature size to another, (e.g. 90 nm to 45 nm etc.). Development of cost effective algorithms to model and simulate innovative computational methods for 90 nm microelectronics, compound semiconductor and other technologies for digital and analog/mixed-signal microelectronics applications will be conducted. Proof-of-concept design approaches to mitigate radiation effects will be identified. Testing and evaluation methodology, of mitigate radiation effects will be identified. Identification of design science approaches to mitigate radiation effects.

PHASE II: Develop innovative computational methods, novel algorithms and Boolean operations, which does not involve triple modular redundancy (TMR) or special transistor structures (i.e. no change to the I-V curves), to mitigate radiation effects: Identify and mitigate design sensitivities in complex integrated circuits, using these methods. Perform trade studies to provide optimized integrated circuits with respect to radiation and electrical performance. Perform trade studies to model reliability of system architectures using unreliable/variable components. Perform virtual Monte Carlo radiation test benching/simulation of complex integrated circuits. The incorporation of predictive radiation response models into high-level abstractions. Perform failure mode reconstruction in complex circuits from test data.

The offeror will develop radiation-hardened-by-designs (RHBD) conversion tools from one foundry to another and/or from one feature size to another, (e.g. 90 nm to 45 nm etc.). The offeror will develop and demonstrate 90 nm radiation effects modeling and simulation methods for these technologies. The offeror will develop and manufacture 90 nm test chips of innovative computational methods and Boolean operations that mitigate radiation design sensitivities in complex integrated circuits of nanotechnology microelectronics.

PHASE III DUAL USE APPLICATIONS: Use of the mitigation methods developed through this effort will support the use of advanced microelectronics for terrestrial applications such as very high performance microprocessor, advanced servers, and very large cache memories.

REFERENCES:
1. IEEE Transactions on Nuclear Science; December 2007, Volume 54, Number 6, Session H: Single Event Effects Mechanisms and Modeling, pages 2297 - 2425

2. IEEE Transactions on Nuclear Science; December 2005, Volume 52, Number 6, Session A Single Even Effects: Mechanisms and Modeling, pages 2104-2231

3. IEEE Transactions on Nuclear Science; December 2005, Volume 52, Number 6, Session F Single Even Effects: Devices and Integrated Circuits, pages 2421-2495

4. JEDEC 57, SEE Test and Characterization Guidelines and Test Method

5. Military Test Method 1019, Steady State Total Ionizing Dose

6. ASTM 1892 ¨C Steady State Total Ionizing Effects Guideline

KEYWORDS: Single-Event Effects, Single-Event Upset, Single-Event Transients, Total Ionizing Dose, Displacement Damage, Nano-Technology, Innovative Computational Methods

DTRA103-003 TITLE: Fabrication and Optimization of High-Speed, High-Voltage-Gradient, High Current Photoconductive Solid-State Switches

TECHNOLOGY AREAS: Materials/Processes, Nuclear Technology

OBJECTIVE: Advance the state-of-the art in solid-state photo-switches for high-speed, high voltage, high current applications such as induction accelerators with an emphasis on lowering the size and cost of induction accelerators and other devices requiring fast high-power switching.

DESCRIPTION: High-speed, high-current, high voltage gradient solid state switches that are driven into the conducting mode by laser light pulses are a key component of many induction accelerators and other devices requiring fast high-voltage, high-current switching. Candidate switch materials may include silicon carbide, gallium nitride, and aluminum nitride, or other materials. In order to advance the state of the art, a bulk breakdown strength of 200 MV/m or greater for voltage-on times of microseconds before the switches are turned on by the laser light and current densities of kiloamperes per square centimeter (for switch on times of tens of nanoseconds) are desired. Other figures of merit are low "on" resistance or equivalently, high carrier density/laser power. The desired "on" resistivity is 10 ohm-cm is or less. The desired "on" state laser intensity is 10 megawatts/square centimeter or less. The desired recombination time is 1 ns or longer for closing switch applications, with a maximum of 5-10 ns, depending upon the specific application. For applications where fast output modulation is required, shorter recombination times leading to sub-nanosecond opening times are desirable. The range of performance parameters, including quantum efficiency of carrier production, carrier lifetime and density, standoff voltage, etc, that can be achieved by fabrication process control, including types and concentration of dopants, heat treatment, etc. should be determined.

PHASE I: The successful Phase I project should address a conceptual design and feasibility study. This should include a comparison of the proposed capability to present technologies, cost/performance impact analysis, and a development/demonstration plan that identifies facility/partnering requirements. It should include switch fabrication with readily available material and tests, with a report on results.

PHASE II: The successful Phase II project will result in the development of prototype devices for a range of applications and demonstrating them in a commercial environment. It will include an optimization of the material tested in Phase I. At the conclusion of Phase II the performer will provide a final report of the demonstrated results and analysis of the commercialization issues/benefits.

PHASE III: The successful Phase III project will result in the large-scale production of well-characterized standardized switches for commercial applications. The switches will have high-reliability electrical connections and optical drive interfaces compatible with the range of commercial applications for these devices. This phase will require environmental and lifetime testing of statistically significant batches of each switch model type in realistic test configurations to qualify them for use in various devices. These tests will be combined with large-scale use of the switches in prototype devices such as induction accelerators and generators of GHz-range electromagnetic energy to provide the switch fabricator with feedback on their performance in real-world applications.

PHASE III DUAL USE APPLICATIONS: The photoconductive switches described here will combine high speed, high voltage standoff capability, and high current. Triggering with laser light allows very fast drive together with high-voltage isolation, which facilitates stacking of the devices to achieve high output voltages. These operating characteristics combined with recent developments in laser technology will enable a large range of applications outside of the DoD. These include applications where the devices are used as closing switches, used in linear mode in high-frequency amplifiers, or used for high-frequency pulse generation in avalanche/high-gain modes. As operating and design experience is gained with DoD sponsored applications of the devices, interest in non-DoD applications will emerge. These may include high-power compact radar and microwave generators, charged-particle accelerators for medical and scientific use, and other devices requiring switches with high voltage standoff and fast on/off times that can be made lighter and more compact by use of these high-performance devices.

REFERENCES:
1. G. Caporaso, "New Trends in Induction Accelerator Technology", Proceeding of the International Workshop on Recent Progress in Induction Linacs, Tsukuba, Japan, 2003.

2. G. Caporaso, et. al., Nucl Instr. and Meth. in Phys. B 261, p. 777 (2007)

3. G. Caporaso, et. al., "High Gradient Induction Accelerator", PAC'07, Albuquerque, June 2007.

4. G. Caporaso, et. al., "Status of the Dielectric Wall Accelerator", PAC'09, Vancouver, Canada, May 2009.

5. J. Sullivan and J. Stanley, "6H-SiC Photoconductive Switches Triggered Below Bandgap Wavelengths", Power Modulator Symposium and 2006 High Voltage Workshop, Washington, D.C. 2006, p. 215 (2006).

6. Gyawali, S. Fessler, C.M. Nunnally, W.C. Islam, N.E., "Comparative Study of Compensated Wide Band Gap Photo Conductive Switch Material for Extrinsic Mode Operations", Proceedings of the 2008 IEEE International Power Modulators and High Voltage Conference, 27-31 May 2008, pp. 5-8.

7. James S. Sullivan and Joel R. Stanley, "Wide Bandgap Extrinsic Photoconductive Switches" IEEE Transactions on Plasma Science, Vol. 36, no. 5, October 2008.

KEYWORDS: solid-state switches, photoconductive, high voltage, fast switching

DTRA103-004 TITLE: Innovative Material Design for Wideband Electromagnetic Shielding

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

OBJECTIVE: Develop a lightweight, low cost, easy to apply or deploy, conformal material that has a higher shielding capability over a broad frequency range (0 ~ 1 GHz) and angle of incidence, to reduce the susceptibility of electronics and systems to electromagnetic disruption.

DESCRIPTION: Military and civilian infrastructure have become increasingly dependent upon sophisticated electronics systems that can be affected, damaged, or destroyed by a variety of intentional and unintentional electromagnetic (EM) insults, including EM pulse (EMP), High Power Microwaves (HPM), lightning and other natural phenomena, and EM interference (EMI). Military ground and air, and comparable civilian systems incorporate some form of shielding and hardening as protection against these hostile EM environments over a broad EM parameter space, including frequency spectrum and angle of incidence. The current method of EM shielding for fixed ground or motorized mobile facilities usually involves the use of heavy metal plates or metallic screens, creating a Faraday cage. For easily transportable (portable) systems, as those carried by personnel, such a method is unacceptable. And with the advent of non-metallic composite materials future systems may inherently suffer from insufficient EM shielding characteristics, which would then require alternative shielding methods and materials.

Modern approaches to the design of specialized EM material, such as metamaterials, or more generally artificial materials, offer new possibilities in developing novel materials to meet future and current EM protection and shielding needs while reducing cost and weight compared to traditional methods. Current state of the art EM material implementations, however, are usually developed for the microwave and higher frequency regimes with limited responses in terms of frequency and incident angles, as well as involving rather highly sophisticated fabrication processes, at least for structured materials. These technology gaps concerning fabrication and material design must be addressed in order to develop practical EM materials that are an improvement in current technology, while still maintaining a useful shielding capability against a range of accidental or intentional EM insults.

PHASE I: The successful Phase I project should design and model materials which have appropriate properties for reflectance, absorption, deflection, dissipation, or re-direction of broadband (Radio Frequency (RF) to Microwave (MW)) EM radiation (~ 0 – 1 GHz) for a wide range of incident angles (~ 0 to 90o) assuming unpolarized plane wave illumination. The material design should have predicted EM shielding properties that meet or exceed those of a good electrical conductor such as copper (~ 80 dB attenuation or greater) while still maintaining a reasonable constraint on thickness compared to the same conductor. The predicted EM response should be relatively flat across the range of both frequency and angle of incidence.

PHASE II: The successful Phase II project should fabricate prototype materials, using low cost fabrication processes, and experimentally test, evaluate, and document the EM characteristics of these materials using unpolarized plane wave illumination. The material must be lightweight, flexible and/or conformal, and easily deployable, compared to a comparable sample of copper or other good electrical conductor, and must meet or exceed the modeled shielding characteristics as described in phase I.

PHASE III: The successful Phase III project should develop commercially viable applications of the developed material to be used as EM shielding of electronic systems on DoD air and ground assets. The product should be flexible, lightweight, and durable in hostile EM environments. Testing and evaluation related to material properties, such as durability, flexibility, and possibly methods of application (depending on material constituents) would need to be performed.

PHASE III DUAL USE APPLICATIONS: The Phase III product should be useful for protection and shielding of commercial ground and air systems as protection against both deliberate and accidental EM insult, such as lightning generated EM pulses and other natural EM phenomena, intentional and unintentional EMI, and electromagnetic compatibility (EMC) applications.

REFERENCES:
1. Seetharamdoo, D., et. al., "Evaluating the Potential Shielding Properties of Periodic Metamaterial Slabs", Int. Symp. on EMC – EMC Europe 2009, pgs. 1-4.

2. Lovat, G., et. al., "Shielding Properties of a Wire-Medium Screen", IEEE Trans. on EMC, Vol. 50, No. 1, Feb. 2008, pg. 80.

3. Holloway, C.L., et. al., "Reflection and Transmission Properites of a Metafilm: With an Application to a Controllable Surface Composed of Resonant Particles, IEEE Trans. on EMC, Vol. 47, No. 4, Nov. 2005, pg. 853.

4. Alu, A., et. al., "Metamaterial Covers Over a Small Aperture", IEEE Trans. on Ant. and Prop., Vol. 54, No. 6, June 2006, pg. 1632.

5. Engheta, N. and Ziolkowski, R.W., Metamaterials: Physics and Engineering Explorations, (IEEE Press, Wiley-Interscience, 2006).

6. Merrill, W., et. al., "Effective Medium Theories for Artificial Materials Composed of Multiple Sizes of Spherical Inclusions in a Host Continuum", IEEE Trans. on Ant. and Prop., Vol. 47, No. 1, Jan. 1999, pg. 142.

7. Yablonovitch, E., "Photonic Crystals: Semiconductors of Light", Sci. Amer., Dec. 2001, pg. 47.

8. Joannopoulos, J. D., et. al., Photonic Crystals: Molding the Flow of Light, (Princeton University Press, 1995).

9. Tesche, F. M., et. al., EMC Analysis Methods and Computational Models, (Wiley, 1999, Ch. 10).

KEYWORDS: EMP, electromagnetic pulse, electromagnetic interference, electronic hardening, electromagnetic shielding, metamaterials, advanced materials

DTRA103-005 TITLE: Low Frequency Electro Magnetic Signatures for Detecting & Discriminating Nuclear/non-nuclear Underground Tests

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Develop physics models and computer algorithms to generate a comprehensive catalog of low frequency magnetic signal signatures arising from a finite set of known and /or possible underground nuclear and non-nuclear test (UGT) devices. In conjunction with conventional seismic techniques, use these signatures to correlate and characterize the test device to discriminate between nuclear and non-nuclear UGT events.

DESCRIPTION: Underground nuclear testing provides an effective means for concealment of clandestine nuclear weapons development programs. In particular, with proper tamping and cavity construction of volume much larger than the weapon size, seismic signals can be masked or
sufficiently distorted to preclude positive identification of a nuclear test through standard seismic identification techniques. This problem has emerged from the so-called evasion technology. Moreover, low-yield nuclear tests can be seismically indistinguishable from similar sized (non-nuclear) high explosive (HE) detonations. HE detonations are very common in the operation of existing mines and oil wells. They are also needed for the exploration of new mineral deposits and oil belts. At the present time, there is no reliable method in the national technical means (NTM) to verify if an UGT explosion is conducted for an economic development program or for a weapon development program in violation of the international comprehensive test ban treaty (CTBT). Any such UGTs are subject to challenges by the international CTBT team.

An alternate but complementary method for detection and discrimination of nuclear vs. non-nuclear underground detonations is clearly needed. A promising candidate is the very low frequency (VLF) magnetic signal which is produced as a characteristic signature of an underground non-nuclear or nuclear test. The waveforms of the magnetic signal emitted in these two types of UGTs have very distinct characteristics. These waveforms can be computed by modeling the physics of signal generation for these two types of UGTs and propagation of the signal from the source to the earth surface. For nuclear UGTs the magnetic signal has been detected at a distance up to 10 kilometers from the test site [Ref. 1]. This signal can provide not only an accurate fiducial time marker of the event, but, with a proper accounting for local earth electrical conductivities and geological anomalies, can also yield information on the device size, burst location, and depth, even in situations where evasion techniques have been employed to mask seismic signal detection and characterization of the event. Moreover, in conjunction with seismic detection techniques, discrimination between nuclear and non-nuclear events should be possible. Recent advances in nano-Tesla and sub-nano-Tesla magnetic signal detection and processing techniques would permit cooperative (or covert) interrogation of identified (or suspected) nuclear test sites. However, to properly interpret these signals, a library of magnetic signal signatures for a variety of burst parameters at locations in question is required.

The signal interpretation is expected to be very difficult due to the uncertain nature of the source, the expected low level of the detected signal strength, and the presence of background natural or man-made noise and clutter. However, by comparison of the measured signal with those of the library and the use of matched filtering and other signal processing technique, an accurate assessment of the device type, yield, and other parameters could be made. Moreover, such a library would also provide information on optimum sensor placement strategy and optimization of magnetic sensor/detector hardware and software. Although qualitative estimates allow order-of-magnitude determination of signal strength and timings, quantitative information on the size, depth, location, and type of detonation can only be provided by detailed analysis and calculation of the generation and propagation of these low frequency magnetic signals to the earth surface at the sensor site. Variations and structuring in deep earth electrical conductivity significantly complicate this problem and most likely will require development of sophisticated computational techniques to accurately predict the low frequency magnetic signal propagation and diffusion through the very complex and possibly highly structured deep earth electrical conductivity. Particular attention must be paid to development of 3-D differencing algorithms or other approaches which are unconditionally stable even for significant spatial variations in earth electrical conductivity and, at the same time, are able to accurately provide (signatures) data on time scales which span from sub-microseconds to several tens of seconds or longer.

PHASE I: Select a promising approach for the accurate calculation of low frequency magnetic signals generated by underground nuclear and HE tests; carry out the preliminary development and implementation of the procedure; and demonstrate the stability, accuracy, and reliability of this approach for a variety of complex sample earth conductivity geometries (including land-ocean interfaces).

PHASE II: Finalize the approach developed under Phase I and initiate the creation of a comprehensive library of magnetic signal signatures for both nuclear and non-nuclear bursts of differing yields and depths for a minimum of three sites designated by DoD.

PHASE III DUAL USE APPLICATIONS: The procedure developed for determining the propagation of low frequency magnetic signals through realistic deep earth conductivities will be directly applicable to the problem of accurate assessment of nuclear high-altitude electromagnetic pulse (HEMP/ E3) environments, where currently, for want of a better approach, a standard uniform conductivity of 10-3 mho/m is assumed. There is a pressing need for a more accurate methodology, since in cases where nuclear HEMP/E3 environments have been calculated using experimentally measured earth electrical conductivity data, deviations by factors of 2-10 from the standard uniform conductivity model have been shown. Addressing this uncertainty will improve the assessment and mitigation of the effects of E3, and natural geomagnetic storms on long haul communications and commercial power lines. Moreover, these same capabilities should be applicable to the commercial problems of geophysical surveying and exploration of the subsurface geological structure for minerals, oil, or natural gas, where VLF magnetic data is acquired and analyzed for prospecting. The use of natural or man-made longwave (ELF/VLF) signal probe technique is already established, but the signal data interpretation/analysis is very difficult and would be greatly improved by the development of a geology dependent signature library. New, advanced signal processing techniques could also be developed and exploited in this commercial area.

REFERENCES:
1. J. Sweeney, "An Investigation of the Usefulness of Extremely Low-Frequency Electromagnetic Measurements for Treaty Verification", LLNL Report No. UCRL-53899, 1989. (UNCLASSIFIED)

KEYWORDS: sensors, underground nuclear testing, seismic, low yield