THE DISPATCH
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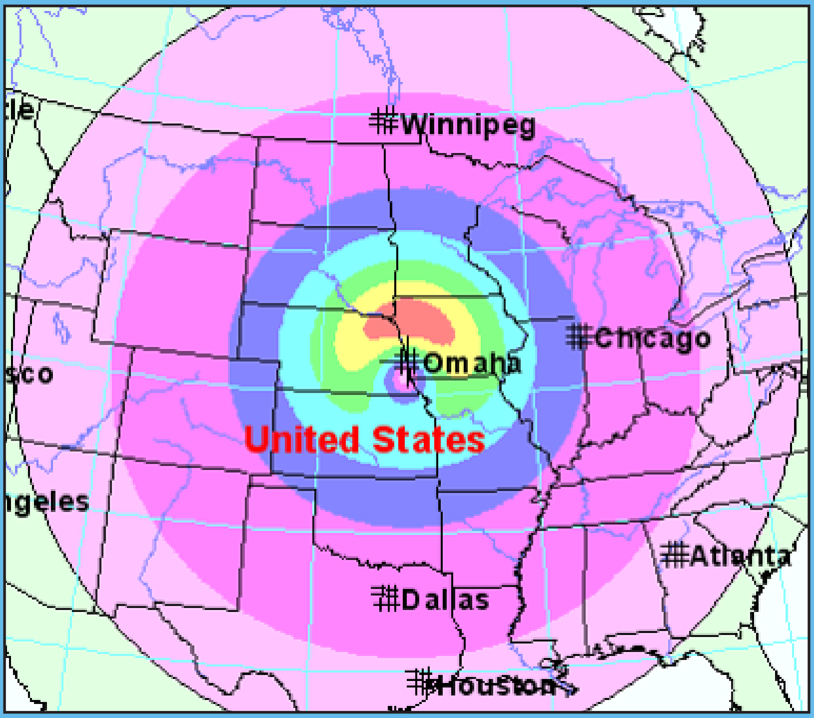
Burst Height Impacts EMP Coverage



EMP coverage area on the ground increases as the height of the burst increases. A nuclear detonation at an altitude of five hundred kilometers over Omaha, Nebraska, will generate an EMP that covers the contiguous land mass of the United States. The electric field strength diminishes with increased distance from ground zero directly under the burst. The asymmetry in contours is a result of the orientation of Earth's magnetic field with respect to the detonation point.

In This Issue

FROM THE CHIEF SCIENTIST

As we move toward our future DTRIAC vision of a "One stop shop" for CWMD information and analysis, we have enlisted the advice of the DTRIAC Senior Advisory Group (SAG). The SAG is made up of senior representatives from across the Agency. These senior leaders provide unique insight from their individual organization / J-Code's plans, priorities, and requirements.

Discussion at the initial meeting revolved around these key questions:

- What should the priorities be to catalog / digitize the DTRIAC Backlog?
- What else should be in collection? Are there Agency products we are missing?
- How can we make DTRIAC more visible and useful?
- In what other ways can DTRIAC support the Knowledge Management needs of the Agency/Community?

From this discussion, action items were formulated that are proving to be an excellent start toward meeting our vision.

Please contact us if you ever have any questions or comments related to the DTRIAC at DTRA-DTRIAC@mail.mil.

Thanks,
Steven Wax
Chief Scientist

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DTRA-DTRIAC@mail.mil
or visit us at:
http://www.dtra.mil/Research/DTRIAC.aspx

Obtaining a STARS account

In order to obtain access to the Defense Threat Reduction Agency's (DTRA) Scientific and Technical Information Archival and Retrieval System (STARS), contact STARS Customer Support at the Defense Threat Reduction Information Analysis Center (DTRIAC) at 505-853-0854 or via e-mail at DTRA-DTRIAC@mail.mil and you will be provided with a STARS User Account Request form. Prior to completing the form and submitting it, you must ensure you meet a number of requirements. You must:

- Be a U.S. citizen
- Hold a FINAL DoD Secret, Top Secret Clearance or DOE L/Q Clearance (Interim clearances are not eligible)
- Be able to provide clearance information to the DTRA in the form of a visit request (not required of DTRA CIV or MIL personnel)
- Obtain DTRA sponsorship (not required of DTRA CIV or MIL personnel)

In Memory of Dr. Charles J. Bridgman

The nuclear weapons effects community lost another great pioneer. Dr. Charles Bridgman passed away late last year. During his long career at the Air Force Institute of Technology he was responsible for teaching nuclear weapons effects to a good portion of the officers working in that field. The following is his obituary from the Dayton Daily News.

BRIDGMAN, Dr. Charles J., Age 85, passed away on November 15, 2015. A graduate of the US Naval Academy '52, he spent several years as an Air Force officer and resigned his commission to teach at the Air Force Institute of Technology (AFIT) where he served as the Chairman for the Nuclear Engineering Program and spent the last 8 years of his career as the Associate Dean of Research, School of Engineering. Upon his retirement, he was named an Emeritus Professor. Jim and his wife, Lucy, were married for 61 years and were founding members of St. Peter Catholic Church in Huber Heights. Author, avid sports fan, car enthusiast, horticulturalist, and aficionado of classical music, fine art and wine, Jim will be dearly missed by family and friends. He is preceded in death by his daughter, Kathy McFadden and survived by his wife, Lucy Bridgman and children: Stephanie Danahy (Daniel); Chuck Bridgman (Susan); Ken Bridgman, Paula Bridgman, Tom Bridgman (Heather) and 11 grandchildren: Terry Kahan, Jessica Rivas, Chris Danahy, Molly McFadden, Tim McFadden, Chelsea Krug, Olivia Boch, Rachael Bridgman, Emma Bridgman, Mia Bridgman and Tommy Bridgman. He is also survived by 8 great grandchildren. Mass of Christian Burial will be held on Tuesday, November 24th at 11:00 am at St. Peter Catholic Church, Huber Heights. Family will receive friends from 5:00 - 8:00 pm on Monday, November 23rd at Marker & Heller Funeral Home, 5844 Troy Pike, Huber Heights, Ohio 45424.

Published in Dayton Daily News on Nov. 22, 2015

- See more at: http://www.legacy.com/obituaries/dayton/obituary.aspx?pid=176605159#sthash.L8ESMQL1.dpuf

FROM THE DTRIAC PROGRAM MANAGER

This issue of DTRIAC Dispatch focuses on nuclear effects; topics include Electromagnetic Pulse Modeling and Simulation, High Fidelity EMP Environment Predictions and High Fidelity SGEMP Simulation tools.

The scientific community lost an outstanding physicist with the passing of Dr Charles Bridgman this past November; be sure to see the article commemorating his achievements in nuclear research.

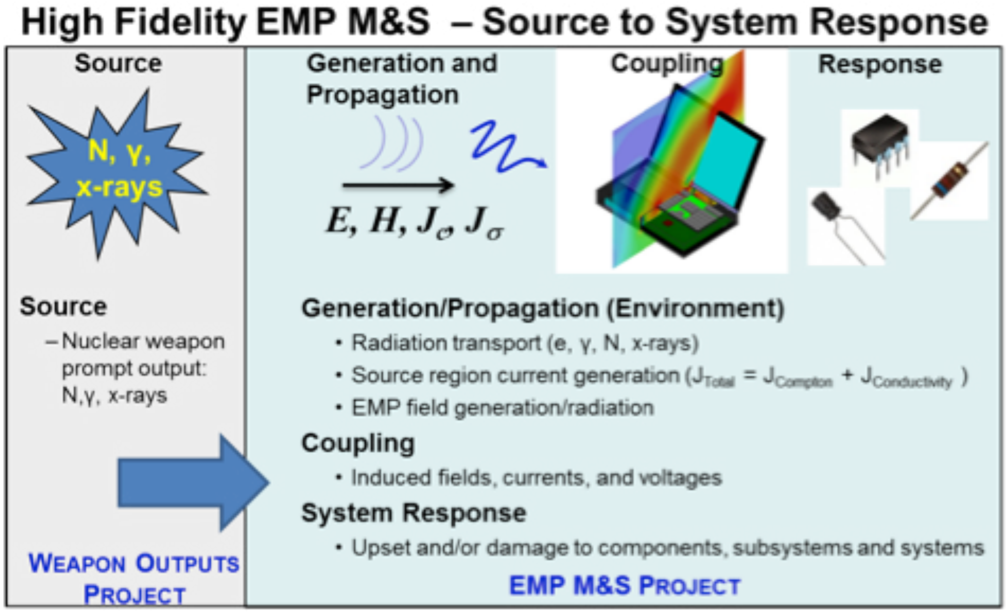
Many of you are familiar with our STARS (Scientific Technical information Archival and Retrieval System), your connection to our massive collection of scientific data and information on nuclear and other weapons of mass destruction. Over the next few months, the system will be upgraded to provide a more user friendly interface and more efficient search capabilities. More to follow in the upcoming Dispatch issue.

If you have written an article you would like to have published in the Dispatch or have any questions or comments related to DTRIAC, please e-mail us at DTRA-DTRIAC@mail.mil.

Linda Qassim
DTRIAC Program Manager

DTRA J9's Electromagnetic Pulse Modeling and Simulation Project

By Lisa Andivahis, DTRA J9, Jonathan Morrow-Jones, ARA, and Steve Swanekamp, NRL



DTRA J9's EMP Project provides M&S tools to predict the environment, coupling and response of systems to the effects of EMP. Weapon source data for the prompt output radiation can be used as input to the EMP tools. (Image courtesy of DTRA funded research)

J9 supports the development and enhancement of nuclear weapon effects modeling and simulation (M&S) tools that provide prediction and assessment capabilities for its customers and the wider DoD user community. This issue of the *Dispatch* features J9's Electromagnetic Pulse (EMP) M&S Project.

Modeling EMP effects on electronic systems is complex and requires in-depth understanding of the full spectrum of phenomena ranging from EMP generation and propagation to the coupling of electromagnetic energy to electronic components and systems and to characterizing the response of those components and systems. Results from EMP models are only as good as the input data they depend on, which for nuclear-generated EMP consists of the weapon output radiation, referred to as prompt output data. The Department of Energy National Laboratories are responsible for generating the spectra and timing prompt output data under DTRA's Weapon Outputs Project. The labs are working to improve the fidelity of the prompt output data contained in the Redbook and Bluebook, as well as provide a new Greybook with historical test data. While further details of the Weapon Outputs Project will not be covered here, the updated Redbook and Bluebook data are now available in electronic form to facilitate their input into high-fidelity EMP M&S tools. The EMP M&S Project has efforts underway to enhance the M&S tools that provide the user with an ability to predict and assess the EMP environment, coupling, and system response. The following two *Dispatch* articles highlight two programs within the EMP M&S Project.

The source for all nuclear-generated EMP begins with the prompt output data from the weapon which consists of neutrons, gamma rays and x-rays. However, the physical mechanisms responsible for generating the various types of EMP differ depending on the height-of-burst (HOB) of a detonation.

Generally, detonations at altitudes above ~20km are considered high-altitude bursts and give rise to high-altitude EMP, or HEMP. HEMP is the name for the effect that manifests itself on the ground due to radiated fields from EMP that is generated in what is called the source, or deposition region. For high-altitude bursts, the source region spans altitudes from about 15 km to 40 km and is the region of the atmosphere where the prompt gamma radiation interacts with the air primarily through Compton scattering (i.e. the scattering of photons from electrons) and generates a flux of high-energy electrons, deemed Compton recoil electrons, each of which in turn cascades to generate on the order of thirty thousand secondary electron-ion pairs. The Compton electrons move predominantly radially away from the burst point at nearly the speed of light and give rise to a Compton current J_C. The secondary electron-ion pairs have no appreciable velocity compared with the Compton electrons and cause the air to become conductive as they drift within the presence of the electric field setup by the separation of charge formed as the Compton recoil electrons move out. The secondary electrons then give rise to a Conduction current, Jσ, whose flow opposes that of the Compton current and partially reduces the magnitude of the resulting EMP.

The mechanism responsible for generating EMP from high-altitude bursts is the Earth's geomagnetic field, without which no radiated EMP fields would escape the source region due to radial symmetry. The EMP is created as the electrons accelerate and spiral along the Earth's magnetic field lines creating transient electric fields and currents responsible for the electromagnetic pulse. The EMP is created with frequencies between about 100KHz and 1GHz which travel efficiently through the atmosphere. The large electric fields (MV/m) associated with these EMP waves can have devastating consequences on electrical equipment.

Three electromagnetic pulses, E1, E2, and E3, are generated with fast, medium, and late arrival times, respectively. The fast pulse, E1, is generated as described above by prompt gamma and x-rays radiating out from the detonation at the speed of light and undergoing Compton scattering. The second pulse to arrive, E2, is decomposed into two parts: E2A results from large-angle and multiple-scattered prompt gammas that take longer to get to the source or conversion layer. E2B is due to prompt neutrons which create secondary gammas through neutron inelastic scattering and capture with the air or ground that leads to secondary gammas. The late time pulse, E3, is due to magneto-hydrodynamic (MHD) effects caused by moving ionized particles that distort the geomagnetic field through their motion. Although present at all altitudes, these MHD effects become far more pronounced for very high-altitude detonations. E3 is decomposed into two parts; that due to the blast, and that due to heave. E3-blast comes from the weapon debris which generates a magnetic bubble in the geomagnetic fields. It is only significant for detonation altitudes above 200 km. E3-heave is caused by heated, ionized air produced by the blast debris rising through and distorting the geomagnetic field.

A surface or near-surface detonation gives rise to

• *See EMP on page 4*

They're Here! Advanced Concentrator Materials Have Arrived

A multi-faceted scientific effort leveraged the collective expertise of several Defense Threat Reduction Agency-funded projects to fuse existing quantitative theoretical modeling and experimental efforts. This combined effort resulted in autonomous processing of diverse chemical species and provided new opportunities for advanced chemical sensor applications. Once complete, the sensors could help unmanned aerial vehicles detect pathogens in aerosol clouds and have several other applicable uses enabling the warfighter to better understand and detect threats.

The project, managed by Dr. Brian Pate of DTRA's Chemical and Biological Technologies Department, was intended to introduce chemical gradients to polymer brushes, polymer hydrogels, and related materials, particularly those with templated channels currently employed by the Braun Research Group from University of Illinois. This would enable directed molecular transport at varied speeds, for separation of mixtures and concentration of analytes at particular functional sites for chemical sensing applications.

Dr. Pate and his team pioneered the effort by providing many of the references and introducing the comparison to bimolecular motors and gel electrophoresis, as well as pushing for consideration of more specific chemical interactions. Dr. Pate emphasized the importance of the aerosol form factor to the DTRA mission space, which led to consideration of means to introduce liquid aerosols to the hydrogel surface, ultimately manifested in the method utilized during the research.

The effort partnered two individual projects, Improving Sensing with Tethered Capture and Surface Diffusion (Dr. Henry Hess, Columbia University) and Surface Directed Molecular Transport, Separation and Concentration (Dr. Paul Braun, University of Illinois). Hess and his team are developing theoretical directed transport models on affinity gradient surfaces and coatings with nanoscale functional sites. The Braun team is using chemical potential gradients in polymer films and brushes to direct the transport, separation and concentration of agents of interest. The long-term goal of these projects is to accelerate analyte capture and detection by developing relevant functional surfaces that directionally transport the analyte towards the sensor detection sites.

Currently, many sensors detect a single agent by detecting various chemical properties such as particle size, reactive state, the charge of the chemical or chemical gradients. However, compound agents are harder to detect and may not be detected with accuracy.

This new research is exploring ways to combine two sensor approaches to accurately characterize an aerosol. When a sample hits a sensor, the different sensor components can move the particles to individual "lanes," directing multiple particles to various parts of the sensor for identification. This allows the sensor to identify more complex agents while reading lower doses of the agent.

Published recently in the Journal of the American Chemical Society, *"Autonomic Molecular Transport by Polymer Films Containing Programmed Chemical Potential Gradients,"* the team describes how their collaboration led to successful design of polyacrylamide hydrogel films containing built-in chemical gradients which afford the spatial manipulation and direct molecular transport of chemicals of interest to the Department of Defense, Chemical and Biological Defense Program. In these joint experiments, a 40-fold concentration of anionic molecules dosed in aerosol form on a polyacrylamide hydrogel film substrate was observed at speeds comparable to transport velocities of biomolecular motors.

The effort is rapidly progressing towards their goal to enable new concepts in chemical and biological transport enhanced sensing and decontamination for defensive applications. This research will enable the warfighter to respond quicker and with greater accuracy to chemical and biological agents.

EMP

• *Continued from page 3*

a phenomenon called source-region EMP or SREMP. Just as for a high-altitude detonation, an EMP can be generated from a surface or low altitude burst. But in this case, the source or deposition region is the immediate truncated-sphere of air surrounding the burst point as the radiation intersects the ground. On or close to the surface of the earth, the effect of the geomagnetic field is negligible on the Compton electron current since the mean free path for recoil electrons near sea level is generally shorter than the distance over which the Earth's magnetic force acts, called the Larmor radius or gyroradius. Instead, the mechanism responsible for generating SREMP is the asymmetry introduced by the air-ground boundary. The ground acts both as a radiation absorber and an electrical conductor. For the downwardly traveling prompt gamma radiation, the ground is an absorber and there is negligible ionization or resulting charge separation penetrating within the ground near the detonation, so there is negligible Compton recoil current or consequent electric field from the Compton current. In the upward direction, a Compton recoil current is created. Because the ground acts as a good conductor, some of the Compton electrons then flow through the ground creating a return current.

The magnitude of electric fields generated from SREMP is much greater than those from a high-altitude detonation; however, the radiated fields from a surface or low altitude detonation affect a much smaller area.

Prompt gamma and x-rays incident on space-based systems create free electrons at material interfaces on the surface as well as deep inside the system. The high energy gamma radiation and x-rays do not play a significant role in the System Generated Electromagnetic Pulse (SGEMP) process because they are too energetic to deposit a significant amount of energy. The main mechanism for electron creation for SGEMP is the photo-electric effect where low energy x-rays from the weapon are absorbed and liberate free electrons. These liberated electrons move both inside and outside of the asset creating currents and inducing conductivity in dielectrics. The transient electron currents generated in this process generate electromagnetic fields which can couple to nearby components that are part of the space-based asset. SGEMP energy can ultimately deposit in electronic devices, causing upset (interrupt, data loss) or damage from electrical overstress.

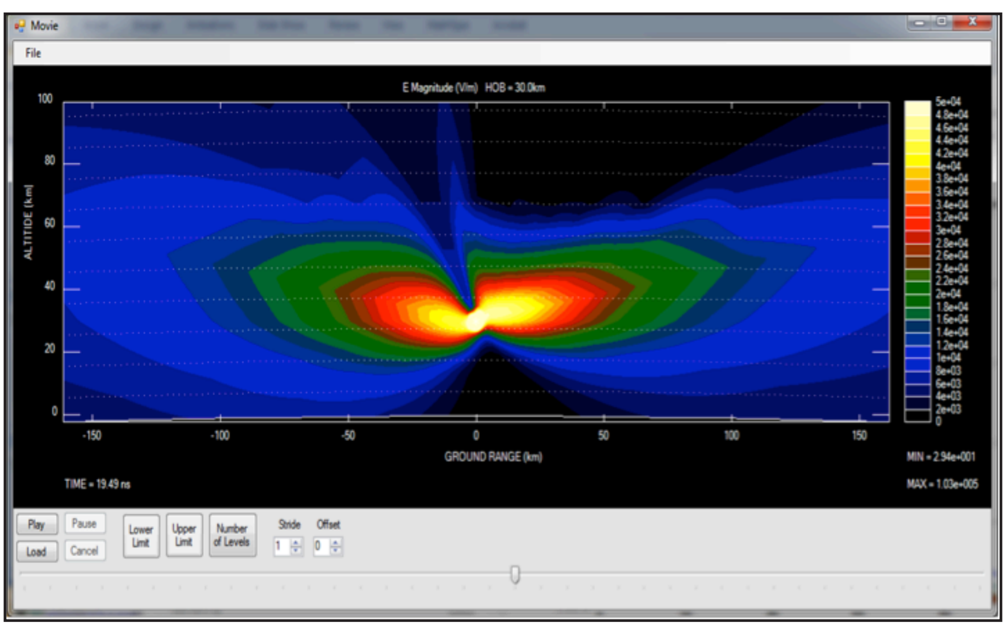
High-fidelity EMP Environment Predictions

By Jonathan Morrow-Jones and Erin Lennon, ARA and Lisa Andivahis, DTRA J9

The effects of nuclear-generated electromagnetic pulse (EMP) have been well known since the mid-1950's and were a topic of great interest during the 1960's when advances were made both in theory and measurement as multiple above ground tests (AGTs) and underground tests (UGTs) were fielded. By the early 1970's computational methods to model HEMP were being investigated using finite-difference calculations on then state-of-the-art computers. For high-altitude bursts, the High-Frequency Approximation (HFA) was proved valid by the Compton High-Altitude Pulse (CHAP) code originally developed in part by Conrad Longmire. The CHAP code is based on a one dimensional, spherically symmetric model that solves Maxwell's Equations in a self-consistent manner in retarded time for calculation of E1. The one-dimensional CHAP-like model has been and continues to be widely used in current-day EMP codes, such as High-altitude Electromagnetic Pulse Target Analysis and Planning System (HEMPTAPS) and a recent, DTRA sponsored, beta-code called High-Fidelity EMP (HiFEMP); however, it does have its shortcomings most notably its neglect of multiple scattering effects and its inability to model 2- and 3-D effects.

For surface or near surface bursts, the calculation of SREMP can be done based solely on the air/ground asymmetry, i.e. neglecting fully any effect from the Earth's geomagnetic force. Source Region Electromagnetic Pulse Target Analysis and Planning System (SREMPTAPS) calculates SREMP and coupling effects but is limited to surface bursts only (HOB = 0). Concurrent with investing in development of HiFEMP, DTRA sponsored a high-fidelity, low-altitude SREMP tool called Low-altitude Extended EMP (LoXEMP). Both LoXEMP and HiFEMP are high-fidelity beta tools (i.e. they have not been made available to the community as they are still under development) developed to run both on high-performance PCs and on large parallel-processing machines such as those within DoD's high performance computing (HPC) centers.

While much work has been done on modeling HEMP and SREMP over the years, and DoD M&S tools such as HEMPTAPS and SREMPTAPS have been validated with test data, the low-altitude regime has proved elusive, and there is no current high-fidelity model that predicts EMP from detonations from about 5 km to 20 km. Any tool that purports to accurately model EMP for all altitudes must include the effects from geomagnetic turning which dominate HEMP and can be approximated in 1-D reasonably, and the effects due to the air-ground asymmetry that drive SREMP but don't lend themselves to a 1-D approximation. A high-fidelity SREMP tool that accurately captures the ground/air asymmetry, as well as effects due to terrain (non-flat earth) and cityscapes required to realistically reflect today's threat scenarios, must account for 3-D where it matters. Fortunately, 3-D calculations, which historically were not computationally feasible, are now possible with today's high performance parallel computers and modern programming techniques.



Sample electric field output from HiFEMP. The graphic illustrates one frame from a movie depicting the magnitude of the electric field generated from EMP in V/m as a function of altitude and ground range for a 30km HOB detonation. The asymmetrical cleft in the field seen at 11 o'clock is the effect of the Earth's geomagnetic field.

In 2015, the DTRA J9 program initiated a new contract to provide the community with a high-fidelity EMP prediction capability for all altitudes and also provide capability to model effects of EMP within a cityscape. The new high-fidelity EMP M&S tool, to be called XEUS which stands for "eXtensible EMP Unified Suite", will unify and enhance DTRA's high-fidelity beta codes HiFEMP and LoXEMP to accommodate modeling EMP for all altitudes. XEUS is expected to be made available to the community in the fall of 2017.

To accommodate the vast difference in scales between the tens-of-kilometers distance traveled for HEMP versus several-kilometer scale indicative of most SREMP scenarios, XEUS is designed with a unified frontend but will have separate computational engines on the backend based on altitude regime.

The approach to providing a 3-D HEMP solution is to use the retarded time formulation of Maxwell's equations in spherical coordinates. The transverse fields are decomposed into ingoing and outgoing waves, the former of which is much smaller and will be ignored to simplify the computation. The angular derivatives are normally ignored in the HFA as used by HiFEMP and CHAP. While in principle Maxwell's equations could be solved in full using HPC resources, it is not feasible as the equations become hyperbolic, and the largest time step becomes constrained by the smallest spatial dimension, due to the Courant condition for stability.

Instead, XEUS will improve the current HiFEMP algorithm to include the angular derivative effects by solving Maxwell's equations, including the angular derivative terms, within differential solid angle volumes. XEUS will divide the 4π volume up into 1000 solid angles to obtain high angular resolution and will refine the parallel implementation to assign the solid angles dynamically to open nodes. The angular derivatives must be calculated simultaneously in each solid angle. This is achieved efficiently using spherical domain decomposition where single computer nodes calculate a single solid angle made up of one or more rays. When the spatial derivative of the ingoing wave is ignored, the computations can proceed in expanding

• *See High-fidelity EMP on page 7*

High-Fidelity SGEMP Simulation Tools

By Dolores Walters, L-3 ATI, Steve Swanekamp, NRL, and Matthew Worstell, DTRA J9 A&AS Contractor

An electromagnetic pulse (EMP) is formed following a nuclear detonation when the high energy (gamma and x-ray) photons, and later neutrons streaming away from the burst point, interact with neutral atoms either in the atmosphere or materials in the line of sight. If this detonation were to take place at high altitude, atmospheric interactions are no longer the dominant absorption mechanism and the photons and neutrons can travel extended distances (hundreds to thousands of kilometers). The first object encountered can be military or civilian space assets. The surface of a system exposed to these high energy photons will experience the creation of large quantities of Compton and photoelectric electrons which are blown off the illuminated parts of the system. The sudden departure of large amounts of charge creates large electromagnetic fields, with electric fields on the order of megavolts per meter and surface magnetic fields that can be as large as kiloamperes per meter. This process is termed System Generated Electromagnetic Pulse (SGEMP). In addition to external SGEMP, the x- and gamma rays can (and will) penetrate light to moderate shielding, repeating the process inside any internal cavities of the system (termed IEMP) as well as in the system cabling (cable SGEMP).

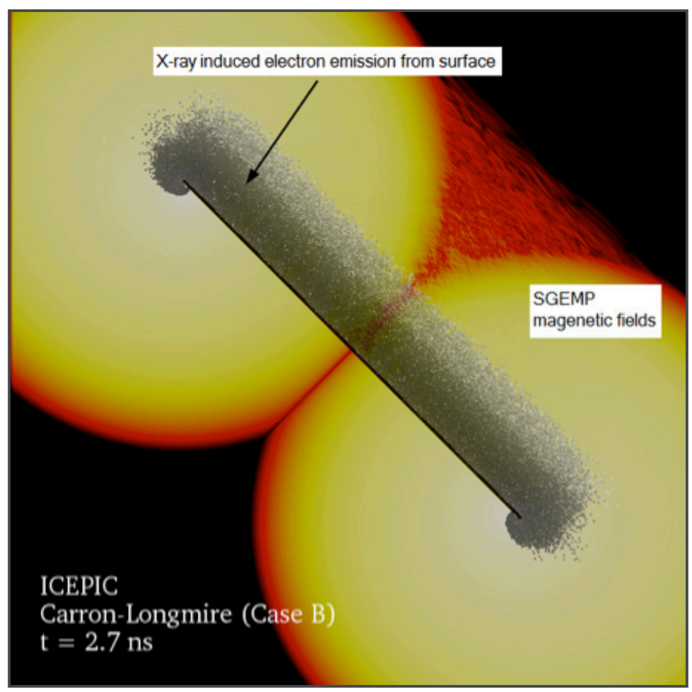
The massive currents and fields generated in an SGEMP event pose a clear, dramatic threat to all space-borne systems. The nature and level of the threat will vary but it can range from temporarily saturating sensors and antennas to interfering with processing (through device latchup and/or upset) to destruction of electronic components, thereby degrading or eliminating the capability to achieve the system's mission. As illustrated through public awareness campaigns such as "A Day Without Space", there is an increased reliance on space-based assets across the DoD and civilian life. This increased reliance magnifies the potential impact of the loss of a space-based commercial or defense system. Many space-based systems rely on constellations of satellites distributed around the globe. This increases the likelihood that at least part of the larger system would be impacted from SGEMP effects produced by a high-altitude nuclear detonation.

As the Department of Defense's nuclear weapons M&S experts, DTRA's Weapons Effects Program is working to better understand, predict, and mitigate the effects of SGEMP following a nuclear detonation. With extremely limited datasets from underground nuclear tests, much of the previous work involved numerical simulations to predict and attempt to quantify the effects of SGEMP. DTRA is investing in a two-pronged approach to enhance its M&S SGEMP capabilities. The first is to expand and enhance the SGEMP non-vacuum algorithms in the PC-based legacy SGEMP tool called Maxwell Equation Equivalent Circuit, or MEEC. The second is to port MEEC's enhanced SGEMP algorithms to the massively parallel Air Force M&S tool Improved Concurrent Electromagnetic Particle-in-Cell, or ICEPIC. This dual approach will provide the SGEMP user community with a PC-based tool to analyze smaller, less complex problems and a high performance computing (HPC) tool for use in conducting full-system analysis. Additionally DTRA J9 is conducting research in collaboration with the Naval Research Laboratory (NRL) to obtain experimental data in physical environments similar to those expected in an SGEMP event. These experiments are designed to stress the current models and will be used to guide the future development of models applicable to a wider range of the expected threat parameter space.

MEEC is a tool which was extensively used in past SGEMP phenomenology exploration. It is a particle-in-cell (PIC) code which self-consistently calculates the electric and magnetic fields created by the motion of "macroparticles" and contains plasma models to represent SGEMP interaction with ambient air. The current effort includes rewriting the legacy FORTRAN version of MEEC in C++ (hence the augmented new name MEEC++) and employing modern programming techniques, as well as upgrading the plasma environment models. The SGEMP problem design strategies are being preserved in the process of increasing complexity and size of the simulations: more robust simulations will be possible using a greater number of macroparticles and fewer simplifying assumptions are needed due to the increased computational capabilities available today. The legacy FORTRAN code has been split into three different components for targeting simulations in vacuum, low-pressure environments, and high-pressure environments. MEEC++ integrates these models into a common design and codebase. MEEC++ is also designed to be a platform for testing new or updated physical models for the underlying processes. MEEC++ can be run on a range of machine sizes, from laptops to a supercomputer. As part of this upgrade, a visualization tool, MEEC-VI, is being developed. This tool allows the user to visually construct the problem input. Using 3-D tools, the user can construct the asset to be exposed to the x-ray sources, define the direction and magnitude of these sources, as well as specify the MEEC++ outputs.

The SGEMP algorithms from MEEC++ are being rewritten as needed and imported into ICEPIC which is also a PIC code, but has been used for a variety of electromagnetic problems and was created and is maintained by the Air Force Research Laboratory (AFRL). ICEPIC utilizes the message-passing interface (MPI) and is optimized for modern, massively parallel, computer architectures that are deployed in the HPC centers. The use of supercomputers

• *See SGEMP on page 7*



|B| (red to yellow contours) and macroparticle positions (grey dots) from an ICEPIC calculation that models intense photo-compton emission of electrons from a thin plate rotated 45° to the Cartesian-conformal gridlines.

High-fidelity EMP

• *Continued from page 5*

shells around the source. The simulation can complete in each shell before moving to the next one further out, making use of MPI (Message Passing Interface) to communicate between nodes or solid angles, and OpenMP (Open Multi-processing) to thread the electron kinematics.

The finite-difference time domain (FDTD) algorithm required for SREMP calculations is daunting when one considers going to 3-D, even with modern and near-future HPC resources. The calculation of a typical SREMP problem is still beyond the resources of most HPC systems. For example, a volume that is 10 km × 10 km × 7 km requires more than 108 GB of RAM, nearly 1000 times more RAM than is available on Sequoia, one of the largest machines available. Given the finite resources of even the best HPC system, each problem setup requires compromise to cover the length scales of interest. For instance, the 2-D model is best for high frequencies in surface and near-surface detonations. Full 3-D calculations can either use a coarser mesh or perform the calculation in a narrower corridor. To the extent that higher frequencies are absorbed close to the source, one might be able to use an expanding mesh, but it is important to confirm the high frequency signal is absorbed before using a mesh that blocks high frequencies propagation. Measurements during atmospheric testing showed frequency content up to 100 MHz out to tens of kilometers, which was the limit of oscilloscope technology at the time.

The FDTD method is readily parallelizable and there are documented solutions for the MPI-only parallel model. XEUS uses shared memory models that can be ported to OpenMP. Further parallelization comes from splitting up the domain among nodes by a slab domain decomposition as illustrated. Run-time and memory usage are optimized by communicating field values only to nearest neighbors.

The high-fidelity models being implemented in XEUS will undergo a fairly rigorous verification and validation (V&V) effort and comply with DTRA Instruction 5000.61 "Verification, Validation, and Accreditation of Models and Simulations". To verify that the models work as designed, results from XEUS will be compared with results from HEMPTAPS, SREMPTAPS and CHAP.

To validate the models for HEMP, there are only two high-altitude tests that measure high-frequency EMP, E1, data: these are Kingfish and Bluegill. XEUS calculations have been compared with the Los Alamos version of CHAP and METAHEMP calculations. METAHEMP is the high-fidelity model that underpins HEMPTAPS. The predicted fields are nearly the same for all three models. An effort will be made to validate or at least baseline E2 and E3 using data from the tests such as Checkmate and Starfish.

For SREMP, Dr. Laurie Triplett of Los Alamos National Laboratory, working with Dr. George Carpenter from SRI, has undertaken a large effort to digitize the complete set of EMP measurements from atmospheric tests, the majority of which occurred near the surface. These lower altitude tests will be used to validate the fall-off of EMP with increasing detonation altitude. The most challenging thing about these tests, however, is that most of them involved experimental weapon designs, and thus the weapon prompt outputs are uncertain. Currently XEUS EMP predictions have been validated using test data from Holly, Walnut, Aztec, and Arkansas. XEUS predictions have been compared with ground measurements, and aircraft measurements, when available. Collaborating with experts working on the DTRA Weapons Outputs Project, the most promising SREMP test measurements will be identified to help prioritize weapons that the DoE labs concentrate on to generate new prompt output calculations for Greybook.

SGEMP

• *Continued from page 6*

produces high-fidelity answers for very large, complex geometries and sources. Geared for subject matter experts and advanced users, the SGEMP version of ICEPIC is being developed as an additional tool to add to the HPC codebase.

A key component in the process of enhancing the SGEMP capability in both MEEC++ and ICEPIC is ensuring the quality of the tools through verification and validation (V&V). DTRA is accomplishing this by pursuing new experimental SGEMP test data through collaboration within DTRA and across the DoD. One such collaboration is with the Pulsed Power Branch of the Plasma Physics Division, part of the Naval Research Laboratory (NRL). This new collaboration between DTRA and NRL on SGEMP-related problems takes advantage of over a decade of experience that NRL has developed working with Sandia in this area. The DTRA-NRL collaboration recently became more formalized through a Memorandum of Understanding between DTRA and the NRL Plasma Physics Division.

A focus of the current work is developing a more realistic air chemistry model for incorporation into SGEMP prediction models through a better understanding of the complex gas chemistry and conductivity generation process in non-vacuum, or thin-air, environments. These environments could be operationally encountered at low altitudes or in interior cavities of a spacecraft. To help validate the air chemistry model, NRL is building an electron-beam pulser with a current density and particle energy capable of producing an environment that is more realistic of the expected ionized SGEMP air environments. In 2016 and 2017, this new SGEMP experimental data will be acquired for regimes that better reproduce the expected environment following a nuclear detonation and will be used to push the current models to their limits of applicability and provide direction for future development of more advanced computer models.

Another collaborative effort just getting underway is at the DTRA West Coast Facility (WCF) operated by L-3 ATI. The WCF provides a host of simulators for testing survivability of components and subsystems. A new series of SGEMP validation experiments are planned for later in 2016 using recently relocated and refurbished vacuum chamber equipment. These experiments will revisit an earlier discrepancy between thin-air SGEMP simulations and experiments, as well as operate across a larger parameter space for better verification of plasma models utilized in both MEEC++ and ICEPIC.

Through DTRA's efforts and collaborations, users in the DoD and the broader community will soon have access to upgraded SGEMP simulation tools. MEEC++ and a version of ICEPIC with the MEEC++ SGEMP algorithms are expected to be available in late 2016. Benefits will range from the extension of existing models and inclusion of new models, to code upgrades using modern programming languages under software configuration control in managed repositories. These new features will increase confidence in the SGEMP tool for the design of space-borne systems. This will give users of the new software tools developed in this program the ability to analyze the severity of SGEMP effects and the effectiveness of hardening (geometry and material choices) with unprecedented confidence.

DTRIAC Collection Additions

DTRA-TR-16-003 Improved Root Normal Size Distributions for Liquid Atomization
This paper identifies two issues with traditional root normal size distributions, of the type used for spray atomization. First, while root normal size distributions are typically expressed in terms of mass mean diameter, they do not actually obtain the correct mass mean diameter. Second, depending on the chosen form, traditional root normal size distributions may exhibit severe non-physical singularities. An alternative root normal size distribution is suggested that avoids these issues. A literature survey finds six possible parameter choices for root normal size distributions. It is found that these parameter choices provide an adequate fit to a wide variety of experimental data, except possibly for the largest droplets. (This report is Distribution A)

DTRA-TR-15-044 Technical Basis for Expedited Processing of Radiation Dose Assessments for NTPR Hiroshima and Nagasaki Participants
This report provides the technical basis for development and use of radiation doses for use in expedited processing of Radiation Dose Assessments (RDAs) for Hiroshima and Nagasaki (H&N) veterans in the Nuclear Test Personnel Review (NTPR) Program. The report describes the general nature of RDAs currently conducted for H&N veterans, and the approach used to define three expedited processing groups EPGs to include virtually all H&N veterans, including occupation forces and prisoners of war in or near Hiroshima or Nagasaki, Japan in 1945-1946. The report discusses the technical methods and assumptions used for estimating "maximized doses" and upper-bound external, internal, skin, and eye lens doses for each EPG. The results of the dose assessment for each EPG are presented and discussed. (This report is Distribution A)

DTRA-TR-15-018 Burkholderia Pseudomallei Data Gap Analysis
The purpose of this review is to identify the major biodefense-relevant data gaps critical to better understanding Burkholderia pseudomallei infections (melioidosis) and how they are acquired, diagnosed, treated and prevented. The following data areas are addressed: epidemiology, animal models, microbiology and genomics, vaccine and medical countermeasures, and predictive modeling. (This report is Distribution A)

DTRA-TR-15-028 Combating Weapons of Mass Destruction: Models, Complexity, and Algorithms in Complex Dynamic and Evolving Networks
This project considers attack and defense problems on networks with respect to WMD attacks. It provides novel optimization models and solutions for network vulnerability assessment and defense measurement in the face of cascading failures and dynamic attacks. The critical infrastructures considered are complex systems which consist of multiple dynamic independent networks interacting to each other. The attacks we considered are dynamic, that is, another attack may be launched during the recovery. (This report is Distribution A)

DTRA-TR-15-058 Plutonium Bioassay Testing of U.S. Atmospheric Nuclear Test Participants and U.S. Occupation Forces of Hiroshima and Nagasaki, Japan
This report documents DTRA's study conducted from 1994 to 2004 to develop a urine bioassay program and investigate the feasibility of this method to complement the atomic veteran dose reconstruction under the Nuclear Test Personnel Review Program. Brookhaven National Laboratory (BNL) used fission track analysis (FTA) to estimate doses to the Marshallese Island population. In this study, BNL's FTA method was evaluated to determine if it can be applied to atomic veterans by measuring plutonium in urine samples. Guided by Congressional legislations (PL 105-85), DTRA conducted a pilot study involving 100 atomic veterans to see if expanded use on atomic veterans was feasible. (This report is Distribution A)

Other Additions to the Collection

DTRA-TR-15-080 Irreversible Phase - Changes in Nanophase RE-doped M2O3 and their Optical Signatures (This report is Distribution A)

DTRA-TR-15-023 Updates to Blast Injury Criteria Models for Nuclear Casualty Estimation (This report is Distribution A)

DTRA-TR-16-006 Transformation and Self-Similarity Properties of Gamma and Weibull Fragment Size Distributions (This report is Distribution A)

DTRA-TR-15-027 Combustion Dynamics of Biocidal Metal-Based Energetic Components in Turbulent Reactive Flow (This report is Distribution A)

DTRA-TR-15-079 HPAC Effects Module RIPDLIPI: Radiation Induced Performance Decrement (RIPD) Lethality Injury Probability Interpolation, Version 3.0 (This report is Distribution C)

DTRA-FTR-15-006 HUMBLE EUCALYPTUS I - 1 through 18 (This report is Distribution F)

DTRA-TR-15-066 Characterization of the PNNL Low-Profile Sensor (This report is Distribution C)

DTRA-TR-16-007 Debris Hazards Due to Overloaded Conventional Construction Facades (This report is Distribution A)

DTRA-TR-15-067 Test Report for the LPC during the Monster Truck Rally Test Campaign (This report is distribution C)

DTRA-TR-15-074 Replacement Technologies for 3He Gas-Filled Neutron Detectors (This report is Distribution E)