Mary Lasky, Chair **InfraGard** EMP SIG and Bill Harris, Vice Chair InfraGard EMP SIG -- Joint Responses to Request for Information (RFI) - **National Space Weather Strategy Update -** submitted May 16, 2018

1. *How can the Federal Government improve internal and external coordination and better inform the long-term guidance and direction for Federal programs and activities that support national preparedness for space weather events?*

A National Framework for Space Weather Preparedness should embrace both man-made and natural-occurring electromagnetic hazards within a common National Security and Space Weather Strategy. Electromagnetic pulse (EMP) hazards and natural-occurring geomagnetic disturbances (GMDs) are so closely linked both by their phenomenology and by their effects that they should be researched, modeled, warned against, and mitigated together. If critical infrastructure systems are newly-designed or retrofitted, or operationally prepared for EMP hazards, they would in most circumstances be adequately protected against GMD hazards. A critical goal of a combined space weather & national security strategy for homeland and global security should be to identify and prioritize common- mode vulnerabilities and common-mode protections respecting EMP and GMD hazards. A high priority, therefore, should also be to identify and assess *unique hazards of man-made EMP*, especially High Altitude EMP (HEMP), and *unique hazards of GMD and other space weather hazards* to terrestrial, trans-oceanic, aerial and space activities.

As emphasized in the EMP Commission Executive Report of July 2017, the Departments of Defense and Energy retain extensive data collections, models, simulations, EMP injection testing assessments, and observations of EMP system impacts observed over more than a half century. It is essential both to expedite critical infrastructure protection and to enhance deterrence that DoD and DoE resources be shared with critical infrastructure owner-operators, state and local governments, and whole of community for comprehensive preparedness.

Including both types of electromagnetic disturbances with the enhanced Space Weather Strategy would be beneficial. The work from the EMP Commission can help the Space Weather community and *vice versa.* See the recently released EMP Commission reports:

- EMP Commission, Volume I, **Assessing the Threat from EMP Attack – Executive Report**, July 2017, approved for release April 9, 2018, released May 9, 2018, and available at: http://www.dtic.mil/dtic/tr/fulltext/u2/1051492.pdf; and
- EMP Commission, Volume II**, Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures**, July 2017, approved for release, April 9, 2018, released May 9, 2018, and available at: http://www.dtic.mil/dtic/tr/fulltext/u2/1051494.pdf

As recommended in the EMP Commission Executive Report, the President should designate a single official to direct and coordinate federal programs and priorities for EMP protection and to assure wider sharing of information, with appropriate safeguards. President Obama's Executive Order *Coordinating Efforts to Prepare the Nation for Space Weather* Events, October 13, 2016, remains in effect. President

Trump should issue a linked and coordinated Executive Order to Protect against Electromagnetic Pulse (EMP) Hazards.

Cost recovery for resiliency from both space weather and man-made EMP is important. The Federal Government could provide tax credits, federal procurement markets, resilient capacity cost recoveries for federal power markets and regional electric transmission organized markets, firm delivery market contract premiums for energy commodities or other essential services, and “best practice” demonstration programs.

Since much of the EMP archival materials remain classified or are withheld *as Controlled Unclassified Information* (CUI), it would be beneficial in grouping GMD and EMP together, so that much of the CUI material may be shared with the Space Weather community as well as utilities and other critical infrastructure owner-operators and vendors developing protective technologies. There is considerable confusion about CUI classification and who may authorize third-party access.

2. *In priority order, how, when and why should the Federal Government invest limited resources to enhance research, technology and innovation to improve observations and understanding of space weather events? Please include near-term and long-term objectives for each investment.*

Combined EMP-GMD threat and response models would be beneficial. Models of effects on Critical Infrastructure are important. Priority should be given to Electric grid, communications & data centers, water/wastewater, transportation, space systems and aviation.

Near-term, continue and expand the United States Geological Survey Geomagnetism Program to complete magnetotelluric surveying of the entire CONUS; to improve and validate 3-D Earth conductivity modeling to understanding the layers of the earth and space; and to improve estimations of (long-line) E3 pulse magnitude and waveforms, and their spatial variations at critical infrastructure facilities. To prioritize hardware protections and feasibility of operational procedures that may be feasible with proactive warnings, 3-D models of geoelectric field variations and conductivity are essential for geomagnetic field and both terrestrial and submarine cable hazard estimations, hazard variability, and protection priority determinations.

Early warning and predictions for both HEMP and GMD events are important: use of tactical warnings to disconnect or shift critical infrastructures (CIs) to standby modes of operation are key research to operations (R2O) goals. Neutral Ground Blockers can be designed to automate uses of GMD and HEMP early warning, if available. Early warning from cyber or delivery systems or E1 pulses may also aid pre-EMP E3 pulse disconnections and rapid termination of loads.

In particular the low-frequency component of the HEMP pulse, the so-called E3 component, is similar to the more time-extended GMD pulses, though potentially of much higher amplitude. Moreover, the above referenced EMP Commission July 2017 report estimates that the E3(B) “heave” pulse amplitude may attain about 3.5 times that projected by EPRI studies (85 V/km vs 24 V/km) and markedly greater than the amplitude generally associated with a GMD pulse (per NERC, 8 V/km, perhaps soon 12 V/km for some regions of Canada), with substantial but inadequately validated voltage reductions (using an *Alpha* factor for reduced E-field projections) at more southerly geomagnetic latitudes. To the contrary, the HEMP E3 waveforms produce far more powerful currents at southerly geomagnetic latitudes but also are modeled by the EMP Commission to produce (lower) E3 fields in the most northerly regions of the CONUS at amplitudes that are always higher than the highest projected GMD E-fields anywhere in the CONUS for a 1-in-100 year solar storm. Other under-review EMP Commission reports address Geomagnetic Disturbance (GMD) pulses as substantially greater than previous NERC/FERC standards (TPL-007-1) assume.

NERC has emphasized GMD hazards primarily from Coronal Mass Ejections (CMEs). Two other relevant classes of GMD hazard deserve accelerated research: long-lasting **Coronal Holes** (CH) coupling with the ionosphere, thence terrestrial electric grids that are associated with a higher rate of large power transformer explosions than those associated with CME events, mainly during nighttime and during solar half-cycle periods of reduced solar geomagnetic B-fields; and **sudden commencement (SC)** solar storms that cause grid transformer losses at lower latitudes**.** Exploiting geomagnetic sensing and geospatial time and event location via AMPERE and IRIDIUM NEXT satellite systems may accelerate understanding of how CH and SC events, in relevant geomagnetic time, may cause transformer losses or damage, and whether equipment that protects against HEMP and GMD will also suffice for protection against persistent coronal holes and as yet unexplained nighttime electrojet accelerations and higher-than-expected nighttime geomagnetic currents.

An effective mitigation strategy to protect and recover all critical infrastructures must recognize that HEMP includes a damaging high frequency component, the ultra-fast E1 component that is not present in the GMD pulse. If designed only for potential GMD, effective protection against the E-3 component is unlikely, partly because E1 and E2 pulses can exacerbate vulnerabilities to E3 pulses that follow promptly. Investing only in GMD protection and not E-3 protection would be a tragically poor investment decision. Moreover, if the E1 component is not included in design requirements, a lack of protection against HEMP will often result even if the E3 component in included in the design requirements.

3. *See separate comments of Stephen Volandt, Vice Chair, InfraGard EMP SIG.*

4. *What innovative tools, platforms, or technologies are needed by the Federal Government and space weather research and development communities to operations for models and observations of space weather phenomena? Please include any barriers to implement the identified tools, platforms or technologies.*

Since only about 2/3rds of the CONUS have been mapped by NSF's Earthscope, this work needs to continue to be able to more accurately understand impacts of space weather on geoelectric conductivity and modeling of GMD and HEMP E3 variability. David Bardin, an expert, has urged Congress to increase funding for USGS mapping and 3-D geomagnetic/geoelectric modeling. Another priority for space weather research to operations (R2O) is to increase the number of geomagnetic observatories in the United States; to reduce unacceptable distances between critical infrastructures and the nearest geomagnetic observatories in the CONUS.

5. In priority order, what opportunities exist to enhance U.S. operational space weather predictions, alerts, and services, for Earth, near-Earth, and deep space applications? Please include any barriers for implementation and utilization of these capabilities.

Link a wider set of space weather observing systems into operational space weather modeling and prediction networks. Examples include AMPERE and Iridium NEXT, and geomagnetic sensors carried by NASA, DoD, UKMET, and other international space systems. Develop models for operational Space Weather and warning systems; design to improve warning, protection, and recovery of critical infrastructures. As we prepare for operational actions based on predictions and alerts, cyber monitoring, neural networks, and artificial intelligence will accelerate the transition from research to prudential operations. These computer programs could be hacked and spoofed – concern for this must be built in. It could be beneficial to conduct research to determine how ultra-fast Artificial Intelligence (AI) can protect industrial control systems from the combined threats of cyber, GMD and EMP.

6. Are there regulatory or other barriers to commercial activities associated with space weather predictions, observations or the transitioning of research to operations? Please list any in priority order, and describe how the barrier(s) impedes activities.

Extensive research has been done on Space Weather and predictions. Linking research to operations would help industry and in reality the citizens of the United States. Among barriers to more efficient utilization of research are: application of Controlled Unclassified Information (CUI) restrictions on access to national security databases and validated technologies for critical infrastructure protection; inadequate cost-recovery mechanisms in the bulk power system (for which FERC is considering resilient capacity pricing), including cost-recovery allowing for space weather warnings that enable cost-savings by the disconnection of electric transmission lines if warning-supported operational procedures can be demonstrated to be cost-effective compared to hardware protection solutions; improved reporting to regulators (e.g. FERC, NRC, NERC) when space weather causes equipment losses or reduced capacity utilization, or avoidable reactive power consumption, or reduced mean life of high cost equipment. FERC will soon review NERC Part 1600 database sharing with the research community. A transformer failure database (TADS) and a generator failure database (GADS) are examples of relevant data that, if more accessible to the space research community could both improve grid reliability and reduce retail customer costs. Cost recovery via capacity markets, R&D tax credits, firm delivery rate differentials, or other market mechanisms are needed beyond the electric utility industry. Improved understanding of changing availability of potable water, through better modeling of space weather-earth weather interactions could support more cost-effective commercial and futures markets for water, build-out of water systems and feasibility of improved water system utilization and conservation. The pricing of most U.S. water systems as cost of service rather than value of service systems may be a regulatory barrier to more effective use of space weather-assisted water forecasting and management.

> *8. What opportunities exist for the United States to marshal the collective resources of like-minded nations….?*

Shared challenges can strengthen both information-sharing and international collaboration. A high priority goal should be to protect global submarine telecom networks from both space weather (GMD E3) and man-made (EMP E1 and E3) pulse damage. About 98 percent of global intercontinental communications and data packets are transmitted by submarine fiber optic cable networks. These are vulnerable to both EMP E1 burnout at landing sites and E3 vulnerabilities of underwater amplified repeaters. A global initiative to protect global submarine cable telecom systems and global supply chains should strengthen international cooperation. See SubTelForum, Issue 99, March 2018, pp. 40-52.