EMP, CME, and GSM:
Preparing for the Risks of Electrical Grid Disruptions at the Coming Grand Solar Minimum

by
Anita Bailey PhD FNP-BC
Contact: elkriver@4securemail.com
Copyright © June 2018

Disclosure:
The author received no compensation from any organization or individual for the research or production of this paper. References are all available in public or scholarly library collections.

INTRODUCTION

When President Obama signed the Executive Order (EO) *Coordinating Efforts to Prepare the Nation for Space Weather Events* on October 13, 2016 (The White House, 2016a), it was nearly a decade and a half after the first volume of the Electromagnetic Pulse (EMP) Commission's Report Executive Summary was published (Foster et al., 2004). That EO was signed 55 years, almost two generations, after the federal government and scientific establishment understood that nuclear detonations in the high atmosphere could damage the electrical grid at a distance from the blast (Huard, 2016). It was over 150 years, six generations, after a solar corona discharge was known to have damaged the rugged and simple electric communication systems of the time (Shea & Smart, 2006).

Even so, this belated EO clarified:

> "*Space weather is a natural hazard that can significantly affect critical infrastructure essential to the economy, social wellbeing, and national security, such as electrical power, water supply, health care, and transportation.*" (The White House, 2016b).

A few years before the EO, a novel about the aftermath of an EMP over the United States, *One Second After* (Forstchen, 2009) caught public attention and laid out the horrendous personal aftereffects of such an event. Forstchen included an unusual element -- a long preface written by Representative Newt Gingrich, who verified the growing concern over the EMP problem. Rep. Gingrich also encouraged readers and officials to seek government-level solutions and remediation of equipment most at risk.

Multiple novelists followed with their own versions of life after EMP, telling stories of people who were highly prepared and technologically advanced, and of others who had to make-do with whatever they had on hand. Titles include: *The Going Home Series; Lights Out (*by David Crawford); *Stacey's Quest; EMP: Equipping Modern Patriots: With a Story of Survival; EMP – Struggle for Survival; After The Event (ATE) (Volume 1);* and *Last Stand: Surviving America's Collapse.* The reading public, a very small proportion of the total populace, was eager to know more.

Television newsman Ted Koppel, a year before the signing of the EO, came out with his own non-fiction book, *Lights Out* (Koppel, 2015). Similar to Forstchen's book, it laid out the vast national vulnerabilities from a cyberattack on the electric grid software architecture. Critics, perhaps unaware of the similar risks already known to occur from cyberattacks and EMPs, compared Koppel's intense, heavily footnoted, and alarming work to pre-Y2K predictions, using words like "fear mongering" and "doomsayer" to describe it. However, Koppel's interview appearances on multiple mainstream media outlets brought wide public attention to grid vulnerabilities. When the press reported that North Korea had placed at least two satellites with grid destroying EMP capabilities in orbit over the United States, a genuine stir of concern rippled across social media.

Suddenly, it seemed, considering the risk of EMP, CME, or other attacks on the grid, with their damaging effects on the social system and oneself, wasn't just for Doomsday Preppers.

PURPOSE

Our main interest in this study is the potential grid-damaging effects of a Coronal Mass Ejection (CME) from the sun during the Grand Solar Minimum. There is a good deal of confusion and contradictory information being promulgated about the risks of CMEs in relation to EMPs or cyberattacks, conflating potential damages and obscuring the picture. This paper is an effort to explore documented sources, their strengths and weaknesses, and then to utilize that information as a groundwork for predicting how a Carrington-class CME or combination of effects may play out during the coming Cold Times. When a reasonable prediction can be made, then appropriate preparedness decisions can follow. Suggestions for preparation will be given at the latter portion of this paper. We'll look at EMPs first, and then compare and contrast their effects with cyberattacks and CMEs. Keep in mind that a CME is one type of EMP.

BACKGROUND:
SUNSPOTS, SOLAR FLARES, CORONAL HOLES, EMPs AND CMEs

In order to comprehensively cover the challenges inherent in CMEs, we need a primary understanding of the similarities and differences between the types of solar incidents that may occur. In brief, there are five basic types of solar events that may impact the earth and grid at different levels of intensity. These are sunspots, solar flares, coronal holes, and EMPs/CMEs.

Sunspots are electrically charged zones visible as discrete brilliant areas on the sun's surface. During solar maxima, sunspots appear frequently and continuously – they are the marker of a solar maximum. During solar minima, spots decrease – a marker of solar minimum -- and during Grand Solar Minima spots may disappear entirely for extended periods of time, as they did during the Maunder Minimum of 1620-1720 (Soon & Yaskal, 2004). Diminished sunspots are associated with extensive cold weather and erratic climate on earth. Note, also, that earth's rotation appears to slow minutely during these types of minima, contributing to deeper cooling as well (Mörner, 2010). If the positive and negative zone charges of a sunspot mingle sufficiently, it leads to a solar flare.

Solar flares are bright pulses that appear on the sun's surface intermittently. They are "local" phenomena on the solar surface although the sunspot may be many times the size of earth. Flares eject white light, ultraviolet light, x-rays, and gamma rays and can generate the kinds of electromagnetic activity that interferes with radio transmissions and generates auroras near earth's polar regions (Coronal Weather Report, 2018).

They are classified by the intensity of the ejection, from the weak A, through B, C, M, and the powerful X-class flare. C-class flares may demonstrate slight effects on earth, but M- and X-class have the potential to generate significant damage to electronics, electrical transformers, grid transmission, radio signals, and may also affect human health. Each level is 10 times more powerful than the preceding one, and there are graduations within each level which is shown by a number. The most powerful X-class flare recorded was an X28 in 2003, which some researchers suggest reached X45, but the detectors on the GOES satellite shut down at X28 (AGU, 2004; NASA, 2011).

"Coronal holes" are areas on the sun's surface that have decreased heat energy and magnetic fields – these variable-sized areas may span a small portion to a half of the side of the sun facing earth during solar minima. Coronal holes decrease in size or migrate toward the sun's north and south poles during solar maxima. They become larger and more pervasive around the sun's equator during solar minima, changing size and shape throughout the course of their existence. Individual holes may continue for hours to days or possibly longer. They are associated with lower Total Solar Irradiance (TSI) and cooling climate on earth.

Coronal holes propagate "solar wind", superheated high speed charged electron and proton particles that interact with earth's atmosphere and magnetic field. Thus, during solar minima when earth's magnetosphere is diminished and provides less protection from solar energies, the charged ionized coronal wind stream is more likely to impact the earth. Coronal hole streams may affect the grid, satellites, GPS, and generate auroras, but they are not EMPs.

EMP is the initialism for *electromagnetic pulse*. An EMP is an incident in which a surge of charged electromagnetic particles is propelled from a specific source, whether natural or man-made[1] (Baker, Pry & Caruso, 2015). Glasstone and Dolan (1977, p. 514) indicated that EMPs following nuclear blasts were observed in the 1950s, whereas Kumar et al. (2015, p.10) stated that first effects were observed in July 1945 following nuclear blasts.

Kumar et al. (2015, p 10-11) differentiates multiple types of EMPs. These include lightning-caused (LEMP); electrostatic discharge (ESD); man-made including from microwave ovens, TVs, radios, mobile phones, and electric power cables; and military nuclear detonation in the upper atmosphere producing gamma rays (NEMP). EMPs may also have been generated by asteroid impacts on the moon (Keysaraju, 2015). Other writers divide EMPs into three primary types, E1, E2, and E3.

Table 1: Types of EMPs

TYPE	SOURCE	TIME TO IMPACT	DURATION	INTENSITY	EFFECTS
E1	Nuclear	Nanoseconds	Nanoseconds	<= 50,000 kV/m	Electronics, communication, satellites
E2	Lightning, Nuclear	Seconds to minutes	Seconds	~100,000 kV/m	Grid, radio, some electronics
E3	CME, Nuclear	Hours to days	Hours to days	Low to high	Grid, power lines =>300 ft, auroras

[1] For PC monitors, "man-made" is a shorthand way of saying "made by humans", not just "made by male individuals". It is used here instead of the cumbersome and circuitous PC terminology "non-natural".

EMP effects can vary widely, depending upon the altitude at which it is generated, the distance from the initiating event, the atmospheric conditions, competing electric or electromagnetic fields, purposeful shielding, density and composition of the material through which it passes, and so forth (Glasstone & Dolan, 1977). EMPs have been found to penetrate 30 inches of soil with a low level of residual energy (1 kV/m) (Kang et al. 2013), and to propagate along underground oil and gas pipelines (Ju-Qiu and Zhi-Shan, 2017). The effects of EMP energy have been associated with a slightly increased incidence of leukemia in exposed workers on EMP projects (Muhm, 1992). Consequently, when we are discussing EMPs, we must speak in the *general* rather than the specific – effects in any given situation may vary from extreme to disappearingly minor.

Do keep in mind that when sources discuss EMPs, they most often seem to consider a *single* nuclear generated event, typically a "modest" nuclear blast set off over the mid-USA. A scenario in which multiple small blasts, launched from covert sites (submarines, disguised fishing vessels, etc) along the US or North American coastline over highly populated areas, would likely have a cascading multiplier effect across the grid – increasing the impact of failures throughout the system. So, too, would multiple blasts timed out over several days or weeks.

A **CME** is a type of EMP (E3), an energetic, ionized, pulse of electromagnetic energy from the sun's corona (NOAA, 2018), and may accompany a large solar flare (Syed et al., 2018). CMEs consist of plasma ejected from the sun's bright corona, its outermost layer. A CME can be larger than the sun itself and be propelled in any direction from the sun's surface, depending on where it is located. Each CME moves outward initially at near the speed of light, with the first particles reaching earth in minutes. "Slower" particles may arrive over the course of days.

During the peak of the approximately 11-year solar cycle, the solar maximum, the sun may release on average 21 CMEs per week. In solar minima, the low point in the solar cycle, there may be 5 per week (Crocket, 2018). Although solar flares are associated with CMEs, a CME may take place without an accompanying flare.

Su et al. (2007) sought to clarify the strength or magnitude of CMEs, and found that their intensity was dependent upon multiple factors:

- soft X-ray peak flare flux
- the CME speed
- six parameters
    - average background magnetic field strength
    - the area of the region where background field strength is counted
    - the magnetic flux of this region
    - the initial shear angle (that is, the magnetic "twist")
    - the final shear angle
    - the change in shear angle

Other sources have described CMEs in terms of billions of tons of charged matter fired from the sun, or by speed (4000 kilometers per second, for example), or as a function of the nano-Tesla (nT) unit. As recently as January 2018, Carley et al., plainly stated: *Despite many years of study, the dominant driver and energy source of coronal mass ejections (CMEs) is still under investigation.* That's a polite way of saying, "we're still not sure what we're looking at".

The effects on humankind depend on the plasma's power, direction, and speed – which are contingent on the location and size of the solar region from which the CME is ejected. The alignment of the "antenna" system also seems to be a factor. The 1859 Carrington Event was a large, possibly x-class CME, which was aimed directly at the earth. There have been many large CMEs ejected from the sun in the 20th and 21st centuries. For example, large CMEs occurred in 1989, 2000, 2013, and 2015 (Johri & Manoharan, 2016), but were not adversely aimed toward earth.

The National Oceanic and Atmospheric Administration (NOAA, 2000), made this statement about one storm, which gives insight into the nature of other ones, as well:

> *The CME impacted Earth's magnetic field on July 15 [2000] and caused a geomagnetic storm that reached category G5 (extreme) levels. This storm was the largest recorded since 1989. Category G5 (extreme) geomagnetic storms may cause some or all of the following system effects: power grids may collapse and transformers experience damage; and spacecraft operations experience extensive surface charging on spacecraft and problems with orientation, uplink/downlink and tracking satellites. Other G5 geomagnetic storm effects include pipeline currents reaching hundreds of amps, HF radio propagation impossible in many areas for one or two days, satellite navigation degraded for days, low-frequency radio navigation out for hours, and the aurora seen as low as the equator.*

OBSERVED AND LATENT EFFECTS OF CMEs

CME effects are well known and historically documented. There is no doubt that coronal mass ejections can and have affected multiple earth-based and satellite systems in the modern era. These appear to act in resonance or as instigators of increased Ground/Geomagnetically Induced Current (GIC), a condition during which the earth acts as a current conductor. We'll review the known effects.

The Carrington Event in a Pre-Grid World

The foundational CME event, most often discussed to explain the damage potentials of these solar storms, is the 1859 Carrington Event. It was not the first instance of local telegraphy being interrupted or damaged by geomagnetically induced currents, but it was the initial case that appeared to span the planet. Named after the astronomer, Richard C. Carrington, who telescopically observed the CME's sudden flash while drawing a large sunspot, the Carrington event was actually at least two pulses on August 28 and September 2, 1859.

Eye witnesses (Green et al., 2006) recounted nighttime aurora and night sky lights so bright it was possible to read a newspaper by it. Aurora were seen as far south as Cuba, and worldwide in East Asia (Hiyashi et al., 2016) and Australia (Humble, 2006) as well as North America. Green et al

(2006) reported that 150,000 miles of telegraph lines in the United States were affected, causing some transmissions to be lost and others to continue even when the lines were disconnected from their battery power, due to line charging from the CME. Telegraph lines that spontaneously burst into flames were responsible for forest fires on several continents, and the newly laid transatlantic cable was damaged so much it failed. One telegrapher was shocked by an arc of electricity that entered his head and exited his feet, much like a lightning bolt. In some telegraph offices, paper near the lines caught fire; in others, the lines themselves became so heated there was concern about them melting.

Assessing the Risk to the Modern Grid

Given that CMEs are most potentially damaging when interacting with long "antenna" and GIC (Geomagnetically or Ground Induced Currents), there are multiple versions of how severe a direct-hit impact may be. Forstchen (2015) offers one novelized potential scenario of a nuclear EMP that mirrors many CME effects, with extensive grid breakdown the endpoint followed by human casualties at extraordinary levels. Others, such as Mitre Corp (2011) dispute worst case conclusions, even as they indicate the risks are quite high and mitigation efforts have yet to be implemented at the time of their publication. As recently as 2017, Graham and Pry, discussing nuclear EMPs indicate that mitigation efforts are limited, taking place slowly, and leave many systems unprotected. So, even among experts, there is concern but little agreement on the how damaging a CME might be, or how prepared the nation might be to weather a solar storm.

During the Carrington time period in 1859, there was no widespread dependence upon a functional electrical grid or internet to manage commerce, banking, communications, aircraft, satellites, or other systems we take for granted today. The EMP Commission report (Foster, 2004) consider the following a portion of 'critical national infrastructure': Electric power; Telecommunications; Banking and finance; Petroleum and natural gas; Transportation; Food; Water; Emergency services; Space-based systems; and Government. Each of these has multiple levels of risk and instability, in the event of a nuclear EMP attack – and potentially if a severe CME should occur.

Other Risks: Military, Satellites, and Global Positioning Systems

Lanzerroti (2014) and DiFino et al. (2014) detail specific effects on satellites and the international space station from geomagnetic and solar events, including:

- Electrical discharges from charged surface materials and charging of interior insulators
- Errors in computer logic systems and storage memory
- False signaling in navigation trackers and telescopes used for research
- Radiation induced electronic degradation due to high total dose or components becoming radioactive
- Solar arrays arcing from electrical discharges
- Damage to solar cells and fogging or discoloration of the materials covering solar cells or the satellite itself

A solar storm in 1967 interfered with national security monitoring systems so much that it almost triggered a nuclear exchange (Pruitt, 2016). The military is known to have developed "hardening" that inhibits the effects of EMPs and CMEs on their vital technology including aircraft, but the extent and nature has been reported in limited detail due to security concerns (Reed, 2012). Matsumoto (2017) pointed out that satellite risks may be higher than estimated, since the 'standard' used to rate their survivability is based on the 1989 CME which damaged Quebec's grid – not a Carrington-class level event. The risks to satellites, consequently, makes satellite-dependent private and mass communication, GPS-navigation, and even makes accessing such systems as block-chain (as in Bitcoin-type arrangements) more problematic.

Vehicles

In the popular view, modern vehicles that utilize electronic circuity can expect to stop in place if an EMP or CME of sufficient magnitude takes place. This idea is not unfounded, since there is evidence that *some* types of electronics are likely to fail or glitch sufficiently to cause the vehicle to mis-perform or shut down its own operation.

In Congressional testimony (Foster et al., 2004) and in a webcast (EMPact Radio, 2011), Dr. William Graham reported his study using an artificially-generated EMP to simulate an overhead nuclear EMP. Although Graham was uncertain of the number during the webcast, in Congressional testimony they state they tested up to 38 types of borrowed cars and 18 trucks, subjected to an artificial EMP that was "modest". Vehicles were tested until they manifested some change, or until the magnitude[2] of the EMP was 50 kV/m.

Non-running vehicles appeared to experience no effects. Those that were running and manifested small errors (blinking dashboard lights, sudden shutdown) typically made it to 25 kV/m to 30 kV/m when this happened; they were not tested beyond this level. Of those that stopped, all but one was restarted by disconnecting and reconnecting the battery (to reset the onboard computer), or simply by turning the ignition key. One pickup had to be returned to the dealer for replacement of an electronic chip. In the same Congressional testimony, Graham stated that cars were not tested at higher levels of EMPs *for concern that the vehicles would be ruined* and his budget did not permit their purchase.

An E1 nuclear EMP at 3 to 4 times the power at which the testing was done, however, would likely affect *most* automobiles to some degree, since it does not require a long "antenna" in order to interact with electronics. Effects from a nuclear E1 or E2 event might include suddenly blinking dash lights, loss of some running operations, immediate engine shutdown, or triggering of safety mechanisms (airbags, automatic braking, etc.).

Testing at Carrington-class energetic levels and on more current automobile models, however, has not been reported. A Carrington-level E3 pulse, perhaps 3 or 4 times the strength of Graham's tests, would still require attachment to longer powerline "antenna" in order to cause damage to vehicles – such as might occur to an electric car plugged in for charging. Vehicles that are

---

[2] Emanuelson (2016) wrote: "… in the United States Starfish Prime event in 1962, the maximum electric field pulse experienced in Hawaii was in the range of 5,000 [5 kV/m] to 5,600 [5.6 kV/m] volts per meter. The worst EMP effects of the Soviet tests over Kazakhstan were about 7,500 volts per meter [7.5 kV/m] in the area where problems were actually documented [damage to diesel generators]. The EMP may have been as high as 10,000 volts per meter [10 kV/m] in un-monitored areas of Kazakhstan, but not any higher. We know that it is possible to rather easily generate 50,000 volts per meter [50 kV/m] with an old second-generation nuclear weapon of the proper design. There are reports that may be possible to make nuclear weapons that will push beyond this 50,000 volts per meter [50 kV/m] limit." [emphasis added – AB]

not in operation at the time of the EMP or CME would be less likely to experience failure or abnormal activity. Emanuelson (2016) notes that cars that are off and stored in a metal garage may have the best protection from CME or nuclear EMP effects. Bear in mind the EMP study was prior to 2005, and automobiles have had more electronics added since that time, possibly increasing their vulnerability. Additionally, no studies of purely electric or dual-combustion/electric automobiles were found, and nothing regarding tests of *autonomous vehicle* safety following even a minor EMP or CME.

Remember that even vehicles that survive a CME or EMP unscathed remain dependent upon fuels that arrive by tanker truck or are pumped utilizing electronic systems, or otherwise utilize the grid. The vehicles may run, but fuel could be unavailable indefinitely.

General Damage

Mitre Corp (2011, p13-15) describe the effect of solar events on other infrastructure:

- *Long electrical conductors*
  - -Electric grids are destabilized and some components are damaged by geomagnetically-induced currents (GICs)
  - –Pipelines experience enhanced corrosion due to GIC
  - – Railroad signals and electrical systems are interrupted or damaged by GIC
- *Satellites*
  - – Gamma-rays and fast particles damage satellite electronics
  - – Radio noise at GPS frequencies causes receivers to lose lock
- *Aviation*
  - – Aircraft on polar routes are re-routed during intense solar storms to maintain communications during radio storms and avoid radiation hazards to passengers and crew
  - – Navigation systems built around GPS are disrupted when solar radio noise interferes with reception of satellite signals
- *Communications*
  - – Radio and electrical interference compromise HF radio and telephone land lines and cell links.

In Congressional testimony, EMP Commission speakers noted that “some” aircraft would likely fail during flight if exposed to a nuclear EMP, although an E3 CME would probably be less likely to cause damage for lack of the extensive “antenna” effect that a CME requires. Those that could still function after an E1/E2 nuclear EMP would seek to land at the nearest airport, assuming a landing site was nearby and suitably outfitted for the particular type of aircraft, and that they could coast in safely. Newer semi-trucks have electronic engine and braking systems and as such may be vulnerable, although no specific test reports were located.

Human Health

There are indications that there are health effects from CMEs and other EMPs. Ben Davidson of *Suspicious0bservers.com* (note “zero” rather than a capital “O”) has presented interesting material on his website related to health risks. Additionally, Zhou et al. (2013) have shown that EMPs are associated with increased permeability of blood-brain barrier; Papathanosopolis et al. (2016) found that solar and geomagnetic events were associated with worsening symptoms of multiple sclerosis; Jiang et al. (2013) found that beta amyloid protein – associated with Alzheimer's dementia in humans – increased in test rats following EMP exposure. And Steinen et al. (2015) found that there was an increased risk of rupture of brain aneurisms linked to solar storm effects – this would potentially result in an immediate hemorrhage in the brain and symptoms of a stroke in the victim.

Furthermore, the medical industry itself is thick with grid-dependent and electronic systems, including the industry emphasis on storing patient medical records on electronic media, the reliance on electronic distribution systems for pharmaceuticals, computer-dependent manufacturing processes for medicines, hospital equipment heavy with electronic components (including vitals monitors, pumps for air and drugs), as well as the routine HVAC management within health care facilities. The sheer magnitude of grid and electronic dependence, with little to no hard copy backup, indicates severe risk to health care management in the event of a systematic breakdown. Cardiac pacemakers, however, not likely to be affected from an E3-type CME due to short line runs and shielding from body mass; E1 and E2 risks may still exist.

Interestingly, Muller (2015) explored the historical accounts related to CMEs and found that there was no apparent direct damage to food plants, agriculture, or livestock. This was, of course, during the pre-industrial agriculture period, and does not account for current grid and electronic dependence.

GSM AND THE RISK OF CME

Historically, during solar minima there are fewer sunspots, solar flares, and CMEs generated than during solar maxima (5 per week in minima versus 21 per week in maxima). However, since earth's magnetosphere is weaker during minima, any CMEs generated would encounter less resistance to impact, and potentially more severe damage could derive from smaller CMEs. The Carrington Event took place during the upswing of Solar Cycle 10, within a 100-month moving average of decreased sunspot numbers (from charts at Nordberg, 2016). In other words, it took place when sunspots were low, just as the sun was coming out of the bottom of the Cycle 9-10 minima. It might not require a Carrington-class event to experience Carrington-class damage to vulnerable infrastructure.

Riley et al (2016) utilized statistical measures to estimate the likelihood of a Carrington Class event impacting the earth. Using his model, he determined that there was a little more than a 10% chance of a CME superstorm hitting earth within the 10 years following his report. In the same study, he mentions other research that estimated Carrington Events occur roughly every 100 years. In other words, their model utilizes the assumption that a Carrington Class CME 100-year earth-impact occurrence is officially overdue, with a 10% chance (1-in-10) of it occurring before 2026.

A previous Riley study (2013) estimated a 1-in-8 chance of a CME superstorm by 2023; the 2016 study updated their model and foundational assumptions. For statisticians reviewing the paper, it must be noted that Riley states that some of his model's components are derived by "subjective" means (p. 54, 56), and by how rigorously "severe event" is defined. That's not necessarily erroneous, but we're left wondering what "subjective" criteria and severity-effect models were used to make the decisions – and whether or not these are legitimate conceptions or merely guesses that fit well with other assumptions.

Historically, large CMEs are more likely to occur during solar maxima than during minima. However, those that do take place during minima *may* be more potentially damaging to the grid, since the earth's magnetosphere has waned and its protective shielding effect is lower. A major solar event took place during the current solar Cycle 24 in the ramp-up phase on July 22, 2012 – it missed the earth by mere days – and NASA reports indicated it could have devasted the grid and other critical infrastructures had it made contact with our planet. Wu and Lepping (2016) found that during 1995 - 2012, monitoring satellites recorded 358 interplanetary shocks originating from solar events – a number that suggests geomagnetic solar activities may be more common than we realize.

Given that the published ability to predict solar storms is virtually absent (Mitre Corp, 2011) and currently based, in part, on models with acknowledged gaps (Riley et al. 2016), we cannot determine an accurate risk. At this time, there is no published way to predict whether or not a CME may occur, where it will be aimed, or how serious the outcome may be. Even so, based on past historical events, we can be confident in two points:

- CMEs occur with frequency, but *severely* impacting earth is a once-in-100- years event.
- An earth-impacting *severe* CME is due at any time.

UNDISCUSSED POTENTIAL RISKS

In reviewing the various documents and studies on EMP and CME, often the writers are intent on explaining or clarifying the risks of a major event – generally utilizing worst-case scenarios to establish the seriousness of the problem. Certainly, a Carrington-class incident would be worst-case, and such an event is already statistically almost 50 years past-due. However, several potential risks have received little attention:

1. Multiple Concurrent or Repeating Pulses

The Carrington event consisted of at least two separate pulsations. The first, a minor ejection, took place on August 28, 1859; the final one was the large ejection on September 1-3 (depending on global position), 1859. The risk today is that after a large, initial CME, people may assume that the damage has been done – and fail to maintain caution and security of supplies as the next pulse arrives.

Equipment that survived a first pulse might be completely incapacitated by second or third pulses. This would apply in particular to systems that were shut down by advance notice (such as components of the grid) prior to the first impact, survived intact, were restarted and then subjected to unexpected impacts hours later. It is also possible that pulses may occur rapidly in succession, so that devices that act as surge protectors are initially damaged and then completely ruined by immediately following subsequent pulses.

This is one of the main dangers of a nuclear EMP – the near-instantaneous E2 pulse following on the E1, generating further damage. There have been no studies that I could find that clarified whether or not an initial CME E3 ejection could be trailed by a second – or third or more – damaging E3 pulse, immediately or hours to days later. Our knowledge base on these events is very thin.

Recall, too, that EMP concerns are typically about a single nuclear-generated EMP over the central US – and the possibility of multiple launches from concealed sites, set off over populated areas for maximum coverage, is not considered. It seems prudent to consider that as a possibility.

2. Overlapping Natural Pulses and Manmade Pulses

Given that national and international players are able, as are we all, to access internet information on potential incoming solar storms, it is not far-fetched to recognize that groups or individuals could piggy-back a high altitude nuclear EMP on the solar effect. Timed to coincide with the incoming CME, such an EMP could wreak even more damage across systems, grids, and infrastructure by adding E1 and E2 pulses alongside the CME's E3 pulse. Overlapping CME and EMP, natural and manmade events, may generate a magnification of damage, without necessarily leaving a perpetrator "signature".

3. Concurrent Natural Pulses and Physical Damage to Grid by Bad Actors

Strategically, terrorists or *national bad actors* of any variety may find an escalation of the negative effects they desire, by timing destructive actions in multiple locations to coincide with an incoming CME. Once again, given internet free access to information on CME generation and progress, timing a physical attack on grid infrastructure or political facilities could worsen any potential CME outcomes – at little expense or effort from the *bad actors.* The outcome could potentially result in both physical damage to electricity-generating facilities, as well as damage along the expected E3 paths. Cleanup from such a situation would be extensive and complicated.

4. Concurrent Natural Pulses with Cyberattacks

Koppel's *Lights Out* (2005) covered the multiple risks of cyberattacks and makes the strong case that backdoors into multiple infrastructure computer systems not only exist, but are merely awaiting triggering by hackers. Just as in the two preceding cases, nations, groups, or individuals wishing to hide their activities may trigger cyberattacks to coincide with an incoming CME – causing damage to grid hardware and software, as well as general social calamity.

5. Overloaded Line Endpoints and Widespread Fire

A potentially major risk that I have rarely seen addressed across the EMP/CME discussion or recommendations, is one that was clearly seen during the Carrington Event: the risk of "antenna" line end-point fires. In 1859, the effect was that telegraph offices connected to the long electrical lines burst into flames from the E3 propagation heating combustible materials. In the same way, the overheated power lines sagged into tree branches, setting forests aflame.

One only needs to visualize the extent of the modern grid, overhanging entire cities, regions, and traversing even the most rural areas of the world. The grid becomes an enormous crisscrossed "antenna" which carries the E3 pulse, sending excess charge through every power outlet in a home or business – into equipment and appliances that are plugged into it. Computers, toasters, cooking stoves, heaters, televisions, security cameras, alarms, lights, and more, could potentially burst into flames or experience component "fry" – much like a nearby lightning strike could cause internal device and electronics damage. Common surge protectors would provide little protection, although large-scale multiple-surge-defense might be a better option. Sagging power lines, too, could generate building and countryside fires.

Imagine one's toaster and coffee maker suddenly igniting in one's home, or wires within walls setting fire to the interior, and the damage that could ensue – particularly if the fire department is suddenly inundated by neighbors with the same problem or cannot be reached due to cell tower or landline phone outage. Should those small fires not be immediately doused, flames would spread and engulf structures – even if one were able to extinguish multiple small fires within one's home, there is no guarantee that neighbors up and down the street would be able or present to do the same in their residences. This would be further complicated by fires starting in electrical generating stations, businesses, high rises, and other facilities. The risk and potential for staggering conflagrations does exist.

6. Absent Federal, State, and Local Disaster Response

Just as noted in the preceding point, disaster response to fire is just as dependent on a functional grid (to send and receive fire calls, and to utilize electronics-dependent fire-fighting equipment), the entire structure of local, state, and federal disaster response systems is grid-dependent. In addition to the need to "call up" disaster workers, each individual who is involved in disaster management requires working transportation, communications equipment, and electronics-dependent emergency supplies of various types including GPS. Each of these may be affected to some degree by a major CME that produces the disaster initially.

Furthermore, it can be expected that if a CME-induced calamity is severe enough, disaster management personnel would be likely to attend to their family and loved one's personal needs before seeking to aid the general population. There is precedent for low turnouts during more conventional disasters, such as hurricanes or snowstorms. Brice et al. (2017) report that 30% of hospital worker respondents said they would stay home following an event, and less than half of hospital employees plan to return to the hospital should a major disaster occur – assuming they were capable of getting there.

In other words, even though emergency management personnel may wish to carry out their professional functions, they simply may be unable to do so. It is also prudent to remember that a CME of Carrington severity would affect the entire nation, surrounding nations, and other continents, as well. Even if it was possible to field an emergency response, it might be spread so thin as to be nearly invisible.

7. **The Vast Majority of the Populace is Unprepared for Common Disasters**

Multiple small-scale studies around the world have asked respondents about their willingness to prepare for common disasters: earthquakes, hurricanes, fires, and so forth (examples: Chan et al., 2014; Cevetkovic, 2017; Najafi et al. 2017) and found low rates of action. One study in tornado country (Chaney et al., 2013) surveyed people who had gone through a disastrous storm to see how the storm affected their preparedness: most still didn't have a weather radio, had no tornado shelter or planned to shelter in their mobile home, past experience didn't seem to influence their decisions, and those who planned to evacuate had picked locations that were excessively far away. People *feel* more prepared when governments enforce the impression of agency preparedness (Basolo et al. 2009), but the populace's actual preparedness remains low.

Even emergency management personnel, those arguably closest to the experience of personal and community calamities, lack preparedness. One emergency manager, a college professor of the subject, stated that she couldn't go longer than two weeks on the supply of food she had at home (Lucas-McEwan, 2012[3]). In a survey of emergency management personnel that I conducted in 2014-15 (unpublished), most respondents stated they had 2 weeks of food or less – and 57% wouldn't even say whether or not they had a flashlight in their home.

The lack of preparedness for *known* disaster risks is not a uniquely domestic issue – it's a human issue. We can hypothesize multiple reasons for this, but the fact remains: the majority of people are unprepared for common disasters. The sad truth is that most will not be ready for any expected "ordinary" calamity or especially for a never-before-seen nation- or world-wide grid-down scenario.

Government at federal, state, and local levels is no better prepared than individuals for EMP-type effects (Baker, Pry & Caruso, 2015). Paperwork has been completed, drills have been run, and studies have been conducted – yet even expected disasters such as hurricanes and floods repeatedly demonstrate that these agencies are not capable of handling multiple, concurrent, widespread threats. A nation-wide grid failure is beyond any agency's capacity to provide help to the populace.

SUMMARY OF THE KNOWN

To summarize what we know with some certainty, we can conclude:

a) During GSM, a CME will occur 3 times per week on average.

b) Most will be low impact or not be earth facing.

c) An earth-facing high intensity CMEs is roughly 50 years past due.

d) There is no way to predict when a CME of severe impact may occur.

e) High intensity CMEs have shut down portions of the electrical grid within recent history.

---

[3] The article created a mini firestorm of controversy. Lucas-McEwan stated that "doomsday preppers" were "selfish" because they concentrated on their own preparedness and did nothing to help their communities. This was, of course, demonstrably erroneous. The author backtracked several times. Eventually the reference was scrubbed from the internet, including off the Way-Back Machine – but the outraged prepper responses can still be found in many articles, commentaries, and forums.

f) High intensity CMEs have caused fires along power lines and at end points.

g) Major grid-dependent or electronic infrastructure, including banks, electricity, hospitals, manufacturing, airlines, GPS, satellites, radio, internet, and cell phones, will experience partial or total failure.

h) As a result of a high intensity CME, some running vehicles may stop or be unable to start, have systemic malfunctions, or be undrivable due to lack of fuel pumping/delivery resources.

i) There may be concurrent highway gridlock from stopped vehicles or accidents resulting from driver confusion.

j) Electric or autonomous vehicles may experience more significant negative effects, including catching fire if plugged into a charging station during a CME.

k) Government and personal preparedness will not be sufficient to respond to the event.

SORTING OUT BALONEY

In the past decade or so, there have been steadily increasing leaks and personal accounts of fudging of scientific data and actual research by scientists and academics, as well as by doctors, pharmaceutical companies, and national meteorological and international climate agencies. NOAA, NASA, and Australia's Bureau of Meteorology (BOM) fudging the climate data to change past and current global and regional temperatures is well known. But, the baloney is much more widespread and pervasive. This was stated eloquently by Marcia Angell, MD in 2009:

> It is simply no longer possible to believe much of the clinical research that is published, or to rely on the judgment of trusted physicians or authoritative medical guidelines. I take no pleasure in this conclusion, which I reached slowly and reluctantly over my two decades as an editor of *The New England Journal of Medicine*.

In fact, the "fake science" problem is so widespread throughout the entire scientific community that Horton (2015) wrote:

> Because this symposium—on the reproducibility and reliability of biomedical research, held at the Wellcome Trust in London last week—touched on one of the most sensitive issues in science today: the idea that something has gone fundamentally wrong with one of our greatest human creations. **The case against science is straightforward: much of the scientific literature, perhaps half, may simply be untrue.** [*Emphasis added*.] Afflicted by studies with small sample sizes, tiny effects, invalid exploratory analyses, and flagrant conflicts of interest, together with an obsession for pursuing fashionable trends of dubious importance, science has taken a turn towards darkness.

The dismal state of scientific enquiry must give us pause. It's intensely challenging to find unbiased and accurate scientific studies on CMEs when the traditional sources fail to disclose that they may be compromised by various agendas and political viewpoints. The fact that the mainstream media revisits the nuclear EMP issue every two years, on average, since 2004 is itself a sign that should make readers wary: *qui bono?*

There's no benefit to the general public if the vulnerable grid gets little remediation to help protect it. Where are the stockpiles of replacement transformers? Who is training grid operators about the signs for immediate protective grid shut down procedures the moment a major incoming CME is detected? Where are the teams of coding experts, crawling across lines of code to pluck out offending cyber hacks?

If remediation is not taking place at a galloping rate, why not? It may be as simple as *normalcy bias:* the subconscious belief that the grid's never completely shut down before so it simply won't, no matter what physics laws are involved. Perhaps the people who understand the risks aren't able to convey them in comprehensible terms to the folks who make decisions about where repairs are made. In a darker mode, perhaps those in charge are holding their cards close and keeping grid-failure as a population-motivating option – people will submit to overlords if their lives have been torn away during social collapse and the overlords offer safety and hope. Or it could be that the actual risks of EMP are wildly overplayed (Gault, 2016), and merely a means to generate funds for the remediation industry.

It becomes doubly challenging to make sound decisions if we must second-guess our sources of reliable information. Good decisions do not arise from false premises, only from honest and trustworthy ones. Consequently, it makes sense to utilize *tested, proven* approaches when seeking the best methods to prepare for incoming CMEs. Absent a sound scientific community to draw from, one must revert to the traditional standard: self-testing, and self-proving, or by demonstrated results from a *trusted* (tested and proven) source. More often than not, that means a reversion to simple "basics".

PERSONAL PREPAREDNESS BEFORE AND AFTER EMP OR CME

Readers who have traversed the previous pages are doubtlessly familiar with the preparedness basics: shelter, water, food, defense. There are many books, YouTubes, articles, and resources to help an individual or family provide their own personal backups for private or public calamities. There is little need to go over these basics here.

However, when we consider the months-to-years of unimaginably large recovery efforts that would follow a Carrington-class CME, it becomes increasingly important to have long-term preparedness *in place* and *ready* for utilization. FEMA and the Red Cross advocate a 72-hour kit of food, water, and medication for emergencies, but an emergency that lasts for months to years will require a much larger capacity, greater planning and expense, and secure storage facilities, *plus* a means to replenish food and water from local resources (i.e., the ability to grow food and collect and purify water).

A year's supply of food basics for each member of the family would be sensible; two years' worth would be better. Calculate 250 pounds each of wheat, rice, beans and corn for starters, for each person – plus 100 pounds of milk powder, 60 pounds sweetener, 10 pounds salt, 100 pounds meat or other protein, 3 gallons of oils, spices, and flavorings, manual grain grinder mill. Substitute if food sensitivities are an issue. Acquire alternative non-electronic cooking methods – propane grill, camp stoves, etc., with extra fuel cannisters -- plus matches or lighters as well.

Consider, too, the general weather and geological effects from a Grand Solar Minimum, already occurring:

- lost crops and failed harvests around the world
- unseasonable heat, drought, flood, or frosts
- snow in mid-summer to historically unprecedented levels
- destructive high winds and tornados in regions where they were previously unknown
- increase in ruinous volcano activity
- increase in seismicity and extreme quakes in high population density major cities
- increasingly fatal lightning and plasma-type discharges

Should these conditions worsen, ordinary agriculture cannot adapt quickly enough to sustain production at current levels – it is *already* suffering. Having the skill and ground to produce your own food is critical. Add these effects to a sudden Carrington-class CME – the loss of grid infrastructure on top of food shortages and climate instability – and the potential for human catastrophe on an inconceivable scale becomes credible. Not only credible but assured. Neither government emergency management agencies, nor governments, will be able to help everyone who needs assistance. We will be on our own.

BACK TO BASICS

Faraday and Data Storage*:* Anything that is dependent upon electronics or electricity will be at risk. One only needs to look around at one's immediate environment to immediately see points of weakness. Many writers on the CME/EMP topic advocate use of Faraday Cages to protect personal electronics from the damaging effects. "Archival" CD-Rs and DVD-Rs which are immune to EMP/CME in a way that flash drives are not can be used to store data for decades, assuming access to a computer to read them. These approaches are widely published and there are many resources to explain and illustrate the basics – a simple search online will provide many low-cost approaches.

Personal Radio and Night Vision: Having electronic devices and communication radios after an EMP/CME, when most people are without them, adds immensely to an individual's or family's ability to weather the storm. Any type of radio communication becomes a force-multiplier for maintaining security of a homestead when others have none. Night vision devices, which are typically quite pricey at thousands of dollars each, could be intensely valuable during dark conditions and in chaotic times – recognizing that these are all laden with electronics and subject to failure during EMPs.

Solar Systems: Solar panels are likely to survive an EMP or CME, but microcontrollers and other electronics likely will not. If your solar system is grid-tied, it may experience sufficient overcharging from the electromagnetic pulse to be damaged beyond use. Separate solar systems from the grid and reduce line length between components as much as possible. Store extra controllers and anything with electronics in the Faraday Cage.

Faraday Downside: Personally, I am much less sanguine about the use of Faraday protection. The underlying assumption behind the use is that there will be a single CME or EMP event, after which one can retrieve one's electronics and get back to using them 'normally'. Should there be multiple repeated pulses at unpredictable intervals – or should a CME be followed or preceded by a purposeful nuclear EMP – stored and prematurely retrieved electronics would be lost.

If you opt to Faraday your electronics, make a point to store extras of the critical items (such as radios, laptops, solar controllers, etc.), and leave at least one set in storage for months to a year after the event. That will give you a fallback supply in case multiple EMPs or CMEs damage the first set you retrieve.

Non-Electronic, Non-Electric Options for Data Storage:

- Although it seems primitive to many modern people, it is still possible to store most important documentation and information *on paper*. Books, financial ledgers, records, and addresses can be preserved free of EMP or CME concerns (short of fire, of course). A large inexpensive supply of pencils, erasers, and paper will assure the ability to record and communicate information forward indefinitely.

- A manually-powered mimeograph with appropriate supplies would allow printing of handouts and newsletters, even when other sources of communication are mute. Manual typewriters and carbon paper would be a secondary means of communication, but supplies would need to be acquired and maintained now.

- Anyone with the ability to use the nearly-forgotten Gregg Shorthand method to record important meetings or decisions would be immensely valuable in a committee or social setting.

- The ability to do arithmetic calculations on paper or in one's head might be a critical aptitude, especially if electronic calculators have failed. Addition and subtraction, multiplication and division – and performing fractions – are nearly lost mental arts. Slide rules for high level calculations can still be found on ebay; the skill to make or use an abacus might be useful as well.

- For vital skills -- such as medical or healing practices, or how to operate critical generators or equipment -- make sure at least two people in your setting share the knowledge. Write must-have protocols or procedures down in a paper binder. If one knowledgeable person becomes incapacitated, you won't lose your only source of information.

Transportation:

- On transportation, Emanuelson (2016) asks *Where would you need to go?* If you are not at your Safe Location, transportation failures (stopped vehicles, highway gridlock, robbery) will likely prevent easy travel even if you have a low-electronics pre-1979 "zombie apocalypse ride". Gas stations and supermarkets will be closed and unable to function. Ideally, you would be in your prepared site if national hostilities suggest an EMP may occur – or advance notice of an incoming CME would take you to your site right away.

- It is possible that a pre-1979 motor vehicle would be resistant to EMP because of an absence of electronics, although low power EMP tests in Russia in the 1960s damaged a completely non-electronic diesel generator, among other equipment. An older vehicle would certainly more readily repaired at home by those with automotive skills. If you plan this route, look for a manual transmission 4-wheel drive truck. Be sure to have extra supplies set back of all critical components, such as distributors, batteries, tires, fuses, wiring, oil and other fluids, and light bulbs – plus fuel that has been treated with Stabil or Pri products. You will need to be able to repair the vehicle as well, so acquire a manual and tools.

- If you are not at your site and must travel, then non-electronic not-fuel-dependent transportation is your option: on foot, bicycle, horseback, or horse drawn cart. You will be a target if you are moving when everyone else is stuck in place. Either get on the road immediately while others are confused and disoriented (preferred) or wait for several weeks until the panic has subsided (riskier due to desperation among survivors).

Other People: Your risks will not only be food, water, and shelter – other people may become desperate and dangerous as early as 2 to 3 days after the event. Hungry neighbors will seek food anywhere, including loose pets. Old scores are likely to be settled violently. Criminals will have a field day since authorities will be occupied elsewhere.

- Street smarts: being alert to one's surroundings, sensing danger, and avoiding it. Most of us have habituated to a relatively safe personal environment (testified to by people wearing earbuds in public or staring at their phones), and do not know how to maintain steady awareness of their surroundings. Practice looking around when entering and exiting your vehicle, noticing who is on the street and what they are doing, perform people-watching when in public, become aware of what people do with their hands, and do so in an unobtrusive way.

- Travel in twos or threes. Walk with your head up, alert to your surroundings. If you sense danger, cross the street or turn back. Avoid being "flanked" (two or three or more people around you) or being forced into what could become a "fatal funnel" (being wedged into traffic so you can't move your car). If you stop, try to keep your back to a wall.

- Become "gray" – decrease your visibility by wearing bland colors and common clothing, such as jeans and an unbranded t-shirt. Avoid camo unless that's normal in your area. No jewelry beyond a simple wedding ring. Ordinary hair styles, simple sturdy shoes or boots.

- Carry personal protective devices such as knives, handguns, tasers, or pepper spray. Practice with these extensively so you can draw and use them quickly and without hesitation. Don't flash them around and don't do anything that is illegal in your area right now.

BEST ROUTE TO PREPAREDNESS FOR YOUR PERSONAL SITUATION

No one source can give you the information or skills you will need in your unique setting and situation. There is only one way to know what will work for you: *try it now.* Here's how:

Take a long weekend and begin it by turning off your power at the breaker. Turn it all off – including your refrigerator. If you have water that comes from public sources, turn it off, too. Turn off your cell phone and computer. *You have just had a CME. The grid is down. The fuel you have in your vehicle is all you have, but all the stores are closed. This is how it will be.*

- Consider heating and cooling – what is your comfort level? Can you live in these conditions?
- How will you flush the toilet? Do you have a place you can haul water from?
- For family members that need medication – how long will your supply last under these conditions?
- Can you filter your water? What other ways do you have to keep it clean and safe for consumption?
- What about cooking? Are there things in the freezer that will be lost if the power is down? What will you eat first? Are you able to can or preserve what you can't immediately eat?
- Do you have a manual can opener, plus a backup in case that one breaks?
- How will you contact family members?
- If you have pets, do they have enough food and water? Who will walk the dog, if that must be done? Might there be risks associated with this?
- How do you occupy your mind and your time? Do you have reading material? Writing paper and supplies? If you have children, what will they do instead of texting, playing video games, shopping, or watching DVDs?
- When night comes, can you navigate the house? Do you have a wind-up clock so you know what time it is?
- What happens if there is a strange noise outside? Do you have a security routine? Are family members skilled in defensive teamwork?
- On day 3, what is wearing most on your nerves? How can you mitigate that annoyance? How's the food in the refrigerator and freezer holding up?

Make notes on your experience and adjust your planning and prepping accordingly.

CONCLUDING THOUGHTS

Estimates vary widely on how many people actively prepare for disasters. One way of defining active preppers is by seeing how many people go to prepper websites and sources online – that provides an estimated 2-3 million active preppers out of a nation of 300 million, or about 1 person out of every hundred. Other estimates place preppers around 68 million, 1 out of 22. The 68 million number is based on extrapolation from a survey of 2000 people, asking whether they bought "survival gear" in the recent past – a flashlight? A bunker? – or saved some money for a rainy day or made a donation to disaster. Given that people who are seriously preparing for ordinary predictable calamities like earthquakes and hurricanes are hard to find, and that "saving money" is NOT prepping, I suspect the lower figure of 2-3 million is more accurate.

Whereas ordinary preparedness is hard to find, people who are aware of and actively preparing for the Grand Solar Minimum are fewer and further between – and those who are alert to the risks of GSM *plus* CME are probably a still smaller percentage. Nevertheless, anyone who is taking even the most rudimentary steps is miles ahead of someone who is carrying on business as usual.

Food and water storage, backyard gardening, looking for a safe "bug out" location, sharpening one's street smarts, learning self-defense skills are all very do-able and satisfying hobbies. For a person with the interest and inclination, refurbishing an old Chevy or Ford "classic" truck can be rewarding and entertaining. Helping children learn mental math tricks is a challenge with lifetime returns. Knitting socks, quilting, and making personalized clothing are home arts that are enjoying a new following as people discover these humble joys. Cooking at home, using fresh ingredients plucked from your own yard – or preparing eggs from chickens raised from chicks – brings a joy that is far in excess of the effort to produce them.

Prepping for the GSM, or for any event associated with it, is not about doom-and-gloom. It is about *gaining options, learning new skills,* and *becoming a self-reliant, self-governing* adult. In a world filled with fearful adult children, that is a power in its own right.

As a final thought, the words of FEMA director Brock Long, from 2017 immediately after Hurricanes Harvey and Irma (Long, 2017):

> *I think that the last 35 days or so have been a gut check for Americans that we do not have a true culture of preparedness in this country. And we've got a lot of work to do. Whether it's in education and being ready, it's not just saying, "Hey, have three days' worth of supplies ready to go." It's greater than that. It's also people having the finances and the savings to be able to overcome simple emergencies. We have to hit the reset button and create a true culture of preparedness starting at a very young age and filtering all the way up.*

REFERENCES

AGU. (2004). Biggest solar flare ever was even bigger than thought. *SpaceRef.* Accessed online http://www.spaceref.com/news/viewpr.html?pid=13844

Angell, M. (2009). Drug companies and Doctors: A Story of Corruption. *New England Review of Books.* Accessed online http://www.nybooks.com/articles/2009/01/15/drug-companies-doctorsa-story-of-corruption

Baker, G., Pry, P.V., Caruso, M. (2015). *The EMP threat: the state of preparedness against the threat of an electromagnetic pulse (EMP) event: joint hearing before the Subcommittee on National Security and the Subcommittee on the Interior of the Committee on Oversight and Government Reform, House of Representatives, One Hundred Fourteenth Congress, first session, May 13, 2015*. Washington: U.S. Government Publishing Office, 2015. http://purl.fdlp.gov/GPO/gpo63775.

Basolo, V., Steinberg, L., Burby, R., Levine, J., Cruz, A., Chihyen, H. (2009). The Effects of Confidence in Government and Information on Perceived and Actual Preparedness for Disasters. *Environment & Behavior, 41*(3), 338-364.

Brice, J. H., Gregg, D., Sawyer, D., & Cyr, J. M. (2017). Survey of Hospital Employees' Personal Preparedness and Willingness to Work Following a Disaster. *Southern Medical Journal, 110*(8), 516-522. doi: 10.14423/SMJ.0000000000000680

Carley, E.P, Vilmer, N., Simões, J.P.A, Ó Fearraigh, B. (2018). Estimation of a CME magnetic field strength using observations of gyrosynchrotron radiation. *Cesra.* Accessed online http://www.astro.gla.ac.uk/users/eduard/cesra/?p=1701

Chan, E. Y. Y., Kim, J. H., Lin, C., Cheung, E. Y. L., & Lee, P. P. Y. (2014). Is Previous Disaster Experience a Good Predictor for Disaster Preparedness in Extreme Poverty Households in Remote Muslim Minority Based Community in China? *Journal of Immigrant and Minority Health* (3), 466. doi: 10.1007/s10903-012-9761-9

Chaney Philip L, a., Weaver Greg S, a., Youngblood Susan A, a., & Pitts Kristin, a. (2013). Household Preparedness for Tornado Hazards: The 2011 Disaster in DeKalb County, Alabama. *Weather, Climate, and Society* (4), 345.

Coronal Weather Report. (2018). Solar Flares and Coronal Mass Ejections. Accessed online http://cse.ssl.berkeley.edu/coronalweather/intro.html

Crockett, C. (2018). What is a coronal mass ejection? *Earthsky: Updates on cosmos and world.* Accessed online http://earthsky.org/space/what-are-coronal-mass-ejections

Cvetković, V. M. (2016). The Relationship Between Educational Level and Citizen Preparedness to Respond to Natural Disasters. *Journal of the Geographical Institute 'Jovan Cvijic' SASA,* 66(2), 237-253. doi: 10.2298/IJGI1602237C

Di Fino, L., Zaconte, V., Stangalini, M., Sparvoli, R., Picozza, P., Piazzesi, R., . . . Scardigli, S. (2014). Solar particle event detected by ALTEA on board the International Space Station. *Journal of Space Weather and Space Climate, Vol 4, p A19 (2014)*, A19. doi: 10.1051/swsc/2014015

Emanuelson, J. (2016). EMP effects on vehicles. *Futurescience.* Accessed online at http://www.futurescience.com/emp/vehicles.html

EMPact Radio (2011). PVP #41 Dr. William Graham on the Dr. Peter Vincent Pry Show. Accessed online at http://www.blogtalkradio.com/empact-radio/2011/03/23/empact-radio-with-dr-peter-vincent-pry

Fagan, B. (2007). *The Little Ice Age: How Climate Made History.* New York: Basic Books

Foster, J.S., Gjelde, E., Graham, W.R. (Chairman), Hermann, R.J., Kluepfel, H.M., Lawson, Gen. R. L., Soper, G.K., Wood, L.L., Woodard, J.B. (2004). *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack Volume 1: Executive Report.* Accessed online http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf

Forstchen, W. (2009). *One Second After.* Forge Books: NY.

Gault, M. (2016). The Overrated Threat from Electromagnetic Pulses: EMPS are scary, but not as scary as the nukes that precede them. *War is Boring.* Accessed online https://medium.com/war-is-boring/the-overrated-threat-from-electromagnetic-pulses-46e92c3efeb9

Glasstone, S., Dolan, P.J. (eds). (1977). *The Effects of Nuclear Weapons* (3rd Ed). US Dept of Defense, US Dept of Energy. Government Printing Office.

Graham, W., & Pry, P.V. (2017). *Statement for the Record*. North Korea Nuclear EMP Attack: An Existential Threat. Accessed online https://docs.house.gov/meetings/HM/HM09/20171012/106467/HHRG-115-HM09-Wstate-PryP-20171012.pdf

Green, J. L., Boardsen, S., Odenwald, S., Humble, J., & Pazamickas, K. A. (2006). Eyewitness reports of the great auroral storm of 1859. *Advances in Space Research, 38*(2), 145-154. doi: https://doi.org/10.1016/j.asr.2005.12.021

Hisashi, H., Kiyomi, I., Harufumi, T., Hiroaki, I., Ryuho, K., Yusuke, E., . . . Kazunari, S. (2016). East Asian observations of low-latitude aurora during the Carrington magnetic storm. *Publications of the Astronomical Society of Japan, 68*(6), 1-13. doi: 10.1093/pasj/psw097

Horton, R. (2015). Offline: What is medicine's 5-sigma? *The Lancet.* Accessed online http://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736%2815%2960696-1.pdf

Howard, T., & Harrison, R. (2013). Stealth Coronal Mass Ejections: A Perspective. *Solar Physics, 285*(1/2), 269-280. doi: 10.1007/s11207-012-0217-0

Huard, P. (2016). The first time the US tested an EMP weapon was a doozy. *Business Insider.* Accessed online http://www.businessinsider.com/first-us-test-emp-weapon-2016-11

Humble, J. E. (2006). The solar events of August/September 1859 – Surviving Australian observations. *Advances in Space Research, 38*, 155-158. doi: 10.1016/j.asr.2005.08.053

Hutchins, T. R., & Overbye, T. J. (2016). Power system dynamic performance during the late-time (E3) high-altitude electromagnetic pulse. 2016 Power Systems Computation Conference (PSCC). doi: 10.1109/PSCC.2016.7540816

IEEE (2003). On the relation between solar activity and seismicity. *IEEE*, p 236. Piscataway, NJ, USA.

Jiang, D.-p., Li, J., Zhang, J., Xu, S.-l., Kuang, F., Lang, H.-y., . . . Guo, G.-z. (2013). Electromagnetic pulse exposure induces overexpression of beta amyloid protein in rats. *Archives of Medical Research, 44*(3), 178-184. doi: 10.1016/j.arcmed.2013.03.005

Johri, A., & Manoharan, P. (2016). An Intense Flare-CME Event in 2015: Propagation and Interaction Effects Between the Sun and Earth's Orbit. *Solar Physics, 291*(5), 1433-1446. doi: 10.1007/s11207-016-0900-7

Ju Ho, L., Sung, S., & Jae Eun, L. (2012). Improving the Critical Infrastructure Protection against to New Crisis: Focused on the EMP Threats. *Journal of Safety and Crisis Management* (2), 44.

Ju-Qiu, Z., & Zhi-Shan, L. (2017). Effects of high-altitude electromagnetic pulse on buried pipeline. *International Journal of Applied Electromagnetics & Mechanics, 55*(4), 507-522. doi: 10.3233/JAE-160141

Kang, H.-D., Oh, I.-Y., & Yook, J.-G. (2013). Analytic modeling of oblique penetration of early-time high altitude electromagnetic pulse into dispersive underground multilayer structures. *Journal of Electromagnetic Waves & Applications, 27*(13), 1649-1659. doi: 10.1080/09205071.2013.821957

Kappenman John, G. (2004). The Evolving Vulnerability of Electric Power Grids. *Space Weather, 2*(1). doi: 10.1029/2003SW000028

Kappenman, J. (2005). An overview of the impulsive geomagnetic field disturbances and power grid impacts associated with the violent Sun-Earth connection events of 29-31 October 2003 and a comparative evaluation with other contemporary storms. *Space Weather*, S08C01: doi:10.1029/2004SW000128.

Kesaraju, S., Mathews, J., Vierinen, J., Perillat, P., & Meisel, D. (2016). A Search for Meteoroid Lunar Impact Generated Electromagnetic Pulses. *Earth, Moon & Planets, 119*(1), 1-21. doi: 10.1007/s11038-016-9496-z

Koppel, T. (2015). *Lights Out: A Cyberattack, a Nation Unprepared, Surviving the Aftermath.* Crown Publishing: New York.

Lanzerotti, L. (2017). Space Weather: Historical and Contemporary Perspectives. *Space Science Review, 212*, 1253-1270. doi: 10.1007/s11214-017-0408-y

Lucas-McEwen, V. (2012). Doomsday preppers are socially selfish. *Emergency Management.* Accessed online at http://www.emergencymgmt.com/emergency-blogs/campus/Doomsday-Preppers-Emergency-Management-112912.html

Kumar, S., & Singh, S. (2015). Study of Electromagnetic Pulse Attack on Electronic Circuits and Hardening Strategies. *International Journal of Recent Research Aspects, 2*(4), 10-14.

Long, B. (2017). FEMA head Brock Long: "We do not have a culture of preparedness in this country." Accessed online at https://www.youtube.com/watch?time_continue=6&v=1LmFMccCzHA

Mann, A. (2012). 1 in 8 Chance of Catastrophic Solar Megastorm by 2020. *Wired.* Accessed online https://www.wired.com/2012/02/massive-solar-flare/

Matsumoto, H. 松., 晴久]. (2017). Estimation of Satellite Failure by Carrington-Class Flare [キャリントン級フレアによる衛星障害の推定]. [Estimation of Satellite Failure by Carrington-Class Flare]. *[Journal of Japan Aviation Institute of Space] 日本航空宇宙学会誌* 65(2), 27-30. doi: 10.14822/kjsass.65.2_27

McManus, D., Carr, H., & Adams, B. (2011). Wireless on the Precipice: The 14th Century Revisited. *Communications of the ACM, 54*(6), 138-143. doi: 10.1145/1953122.1953155

Mekhaldi, F., McConnell, J. R., Adolphi, F., Arienzo, M. M., Chellman, N. J., Maselli, O. J., . . . Muscheler, R. (2017). No Coincident Nitrate Enhancement Events in Polar Ice Cores Following the Largest Known Solar Storms. *Journal of Geophysical Research - Atmospheres, 122*(21), 11,900.

Mitre Corp. (2011). Impacts of Severe Space Weather on the Electric Grid. JASON, The Mitre Corporation.

Mörner, N. (2010). Solar Minima, Earth's rotation and Little Ice Ages in the past and in the future: The North Atlantic–European case. *Global and Planetary Change, 72*, 282-293. doi: 10.1016/j.gloplacha.2010.01.004

Muhm, J. M. (1992). Mortality investigation of workers in an electromagnetic pulse test program. *Journal of Occupational Medicine.: Official Publication Of The Industrial Medical Association, 34*(3), 287-292.

Muller, C. (2014). The Carrington Solar Flares of 1859: Consequences on Life. *Origins of Life and Evolution of Biospheres, 44*(3), 185-195.

Najafi, M., Ardalan, A., Akbarisari, A., Noorbala, A. A., & Elmi, H. (2017). The Theory of Planned Behavior and Disaster Preparedness. *Plos Currents, 9*. doi: 10.1371/currents.dis.4da18e0f1479bf6c0a94b29e0dbf4a72

NASA. (2011). Solar Flares: What does it take to be X-class? Accessed online https://www.nasa.gov/mission_pages/sunearth/news/X-class-flares.html

Neilsen, K. (2017). Dirty Fires: Cosmic Pollution and the Solar Storm of 1859. *19: Interdisciplinary Studies in the Long Nineteenth Century* (25), 1-8. doi: 10.16995/ntn.788

NOAA. (2000). NOAA SEC Space Weather Outlook 07-18-2000. *SpaceRef.* Accessed online http://www.spaceref.com/news/viewsr.html?pid=689

NOAA. (2018). Coronal Mass Ejections. *Space Weather Prediction Center,* National Oceanic Atmospheric Administration. Accessed online https://www.swpc.noaa.gov/ phenomena/coronal-mass-ejections

Nordberg, J. (2016). Heliometeorology [charts]. Accessed online http://www.grandunification.com/hypertext/Heliometeorology.html

Papathanasopoulos, P., Preka-Papadema, P., Gkotsinas, A., Dimisianos, N., Hillaris, A., Katsavrias, C., . . . Kargiotis, O. (2016). The possible effects of the solar and geomagnetic activity on multiple sclerosis. *Clinical Neurology and Neurosurgery, 146*, 82-89. doi: 10.1016/j.clineuro.2016.04.023

Pruitt, S. (August 12, 2016). New Study Suggests Solar Storm in 1967 Nearly Caused Nuclear War. *History.com*. Retrieved from https://www.history.com/news/new-study-suggests-solar-storm-in-1967-nearly-caused-nuclear-war

Reed, J. (2012). We're still worrying about EMPs. DefenseTech. *Military.com.* Accessed online https://www.military.com/defensetech/2012/02/29/were-still-worrying-about-emps

Riley, P., & Love, J. J. (2017). Extreme geomagnetic storms: Probabilistic forecasts and their uncertainties. *Space Weather: The International Journal Of Research & Applications*, *15*(1), 53. doi:10.1002/2016SW001470

Saiz, E., Guerrero, A., Cid, C., Palacios, J., & Cerrato, Y. (2016). Searching for Carrington-like events and their signatures and triggers.

Shea, M. A., & Smart, D. F. (2006). Compendium of the eight articles on the "Carrington Event" attributed to or written by Elias Loomis in the American Journal of Science, 1859–1861. *Advances in Space Research, 38*, 313-385. doi: 10.1016/j.asr.2006.07.005

Soon, W., Yaskel, S. (2004). *Maunder Minimum: And the Variable Sun-Earth Connection.* New Jersey: World Scientific Pub Co Inc.

Stienen, M. N., Smoll, N. R., Battaglia, M., Schatlo, B., Woernle, C. M., Fung, C., Rothlisberger, M., Daniel, R.T., Fathi, A., Fandino, J., Hildebrandt, G., Schaller, K., & Bijlenga, P. (2015). Intracranial Aneurysm Rupture Is Predicted by Measures of Solar Activity. *World Neurosurgery, 83*(4), 588-595. doi: 10.1016/j.wneu.2014.12.021

Su, Y., Van Ballegooijen, A., McCaughey, J., Deluca, E., Reeves, K., Golub, L. (2007). What determines the intensity of solar flare/CME events? *The Astrophysical Journal*, 665:1448-1459

Syed Ibrahim, M., Shanmugaraju, A., Moon, Y. j., Vrsnak, B., & Umapathy, S. (2018). Properties and relationship between solar eruptive flares and Coronal Mass Ejections during rising phase of Solar Cycles 23 and 24. *Advances in Space Research, 61*(1), 540-551. doi: 10.1016/j.asr.2017.09.015

The White House (2016a). *Executive Order: Preparing the Nation for Space Weather Events.* Accessed online https://obamawhitehouse.archives.gov/the-press-office/2016/10/13/executive-order-coordinating-efforts-prepare-nation-space-weather-events

The White House (2016b). *Preparing the Nation for Space Weather: New Executive Order*. United States: Office of Science and Technology Policy Blog.

Thomas, B. C., Arkenberg, K. R., & Snyder Ii, B. R. (2011). Revisiting the Carrington Event: Updated modeling of atmospheric effects.

Wu, C.-C., & Lepping, R. (2016). Relationships Among Geomagnetic Storms, Interplanetary Shocks, Magnetic Clouds, and Sunspot Number During 1995 - 2012. *Solar Physics, 291*(1), 265-284. doi: 10.1007/s11207-015-0806-9

Zhou, J. X., Ding, G. R., Zhang, J., Zhou, Y. C., Zhang, Y. J., & Guo, G. Z. (2013). Detrimental effect of electromagnetic pulse exposure on permeability of in vitro blood-brain-barrier model. *Biomedical and Environmental Sciences: BES, 26*(2), 128-137. doi: 10.3967/0895-3988.2013.02.007