



# Black Sky Hazards: Description and Impact

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# EMP

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THE BLACK SKY HAZARDS RESOURCE SERIES

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A series of brief reviews of emerging, severe Black Sky hazards, including threat characterization and summaries of societal and infrastructure impact.





Chicago Blackout, October 9, 2000

## Black Sky Hazards

In the modern world, increasing organic connectivity among all our lifeline infrastructures has brought us unprecedented capabilities. At the same time, the interconnectivity which empowers our world has created a wide array of infrastructure interdependencies that put at risk all the resources that support and enable our lives.

"Black Sky" hazards represent a new class of emerging malicious and natural threats, complicated by these interdependencies, taking place at a level of severity that would cause an unprecedented subcontinent-scale power outage lasting weeks or months. Cyber attacks, EMP<sup>1</sup> attacks, kinetic assault on key power grid nodes, extreme terrestrial or space weather<sup>2</sup> or severe regional earthquake zones,<sup>3</sup> taking place at such "Black Sky" levels, would also cause cascading failures of all our other, interdependent infrastructures.

This BLACK SKY HAZARDS RESOURCE SERIES, now under development, provides summary-level reviews of each of these hazards. It serves as a foundation for focused resilience investment and for the coordinated, multi-sector planning that will be essential for infrastructure restoration, response and recovery to save and sustain lives, and avoid catastrophic impacts in these extreme scenarios.

This Black Sky information series is provided as a resource, responding to a fundamental question:

**Does our nation wish to be prepared to survive a Black Sky hazard?**

The material that follows, and the parallel documents being developed for each of the Black Sky hazard categories, are designed to provide brief, summary-level information that may be helpful in planning by those infrastructure owners, operators and their partners who are working to provide a positive answer to this question.



A

# THE **EMP** **THREAT**

## EMP Definition and Summary

An electromagnetic pulse (EMP) is produced whenever a nuclear warhead is detonated in the upper atmosphere. This pulse produces a powerful, damaging electromagnetic field covering a subcontinent-scale region – easily, for example, spanning 1/3 or more of the United States.

The pulse includes two components: “E1,” a very short microsecond-class component, disrupts and damages conventional electronics such as computers and microchip-based utility control systems. “E3,” which can last for minutes, can permanently damage unprotected high voltage electrical equipment, with impacts similar to the effects of severe space weather.

The nuclear warhead in an EMP attack can reach the upper atmosphere in a missile, a satellite in low earth orbit, or even a weather balloon. Precise positioning of warhead detonation is not important, given the pulse’s extremely large footprint.

An EMP attack with even a single warhead would cause widely distributed damage to the national power grid, causing an unprecedented multi-state power outage. Without focused resilience investments and multi-sector restoration support planning, the blackout would continue for months, with catastrophic consequences. The resulting breakdown of water, wastewater and food processing and delivery systems would lead to millions of deaths from dehydration, starvation and disease.

Adversary countries or terrorist organizations with access to a small number of nuclear warheads may choose this mode of attack, rather than using their limited arsenal on a small number of ground targets. There is evidence that both North Korea and Iran have developed such plans.

Cost-effective strategies for power grid protection could protect a regionally-distributed grid “backbone,” providing a foundation for power restoration that, if combined with coordinated planning by other lifeline infrastructure sectors, would dramatically improve the speed of recovery. In that case, continuous or only briefly interrupted power would be assured for designated portions of the power grid. With preplanned support from the electric subsector’s partners, power could then be steadily restored and the region’s population sustained, reaching most of the affected area within weeks, rather than months or years.

For decades, U.S. and allied military agencies have protected critical military assets from an EMP attack. However, with some notable exceptions, civil infrastructure resilience investments for this emerging Black Sky threat have not yet been widely implemented.



People leaving Manhattan during 2003 Blackout

## Societal Impact

National power grids are sometimes referred to as "the World's Largest Machines," with many tens of thousands of power substations and a vast array of low and high voltage components distributed all across modern nations. An EMP strike would shut down large regions of this continent-spanning network, with widely distributed damage enormously complicating grid restoration efforts.

Even a single nuclear warhead detonating high above the eastern half of the United States could shut down most or all of the Eastern Interconnection that powers roughly half of the nation. Caused by random, statistical damage to grid components distributed across many States, the outage could extend from Florida to Maine and from Kansas to Washington D.C., followed within days by cascading failures of all other lifeline infrastructures in those regions. Tapwater, functioning toilets and sewage systems, food production and delivery, pharmaceutical supplies, communication, transportation, local and national security and distribution of all normally-available products and services would come to a halt.

Without focused, cost effective resilience investment and coordinated multi-sector plans for restoration support, finding, repairing and replacing damaged components would be difficult and time consuming even under ordinary circumstances. In the disrupted environment that would result from such a massive blackout, restoration would not be possible on time scales that could allow for effective national continuity. Millions would die.



## Infrastructure Effects

### Physical Damage

The damage associated with EMP is statistical in nature and, based on a wide range of testing<sup>4</sup>, a relatively small and randomly distributed portion of electrical equipment would be expected to fail. However, while this leads to some unique opportunities, without cost-effective, focused resilience investments and operational planning, this randomly distributed damage will cause a widespread, long duration power outage due to several interrelated, compounding effects.

- **Control Centers and Low Power Electronics:** Comprised of thousands of microchip-based interactive SCADA systems, the control centers that keep the power grid operating would be disrupted and damaged. Without preplanning, repairs would be extremely difficult, at best. It would involve finding and bringing in expert controls-hardware engineering teams, locating widely-distributed, damaged SCADA systems and other low power components, attempting to find replacement components -- typically from remote facilities unlikely to be functioning -- and then repairing, reintegrating and testing the rebuilt facility.
- **Generating Stations:** With a large plant burning fuel at a rate equivalent to roughly a ton of TNT per second, the generator's electronic controller is vital to properly handle the huge forces involved, and avoid damage to the massive rotating hardware. Conventional Electromagnetic Interference (EMI) limits near such controllers are typically a few volts per meter.<sup>5</sup> EMP field strength is rated at more than 20,000 volts per meter, more than one thousand times



this level, massively exceeding levels that can disrupt operation of the sensitive controller, likely causing serious damage to the generator hardware.. Repair or replacement of generators or heavy equipment at these installations normally requires *months or years*.<sup>6</sup> In a severely disrupted, Black Sky environment, if possible at all, far more time would be required.

- **Extra High Voltage (EHV) Transformers, and Grid Instability:** Large EHV transformers have unique vulnerability to this hazard, due to Geomagnetically Induced Current (GIC) from the E3 EMP pulse component. GIC flowing through the grid can cause thermal damage to some of these massive, long-lead transformers. Where required, replacing damaged EHV transformers, critical to power transmission across the nation, generally requires months or years under normal conditions.

Those EHV transformers that continue to function will be driven into “saturation,” an unplanned condition that could cause severe harmonics: voltage instabilities that would be conveyed throughout the grid and expand the scale of grid disruption and damage already caused by the E1 pulse component.

In fact, interaction between the impacts of the EMP E1 and E3 pulses is likely to be particularly dangerous. For example, with E1 effects disrupting the normal grid shut down process, power that continues to flow through portions of the grid that remain in operation will tend to severely overload remaining transmission systems, which could further damage critical EHV transformers.



## Restoration Challenges

Without focused resilience measures and coordinated, multi-sector plans for restoration support, restoration would have to take place in an environment with many complex challenges.

- **Limited Tech Labor Availability:** Without preplanned community support for Black Sky conditions, engineers and technicians would face conflicting choices that would greatly limit their availability. Many would feel compelled to help their families deal with the crisis, rather than supporting power restoration.
- **Transportation:** Without careful coordinated Black Sky planning, restoration teams that do seek to deploy would face severe transportation hurdles, with unplanned migration and lack of operating gas stations causing gridlock on major highways and in city centers.
- **Communication:** Today there is no common, broadly deployed Black Sky hazard-compatible emergency communication system. Communication between generation, transmission and distribution companies, and with the major electricity “load” customers they will need to work with, would generally be impossible.
- **Working in the dark:** Cost effective EMP resilience measures will be vital to support power grid restoration efforts following an EMP attack. Without these capabilities, restoration personnel would generally be unable to work outward from an EMP-protected, still-operating grid backbone, severely limiting their ability to find and repair damage throughout the large areas affected.



- **Security:** If Black Sky-compatible emergency plans and resources are unavailable to sustain the population, physical security, fire safety and a wide range of related challenges would impede restorers.
- **Critical interdependencies:** Multi-sector Black Sky planning, including a focus on the unique requirements for EMP, will be crucial to ensure lifeline infrastructures have pre-coordinated plans to sustain the population and support power restoration.
- Without such planning, with cascading failures of other infrastructures, operation of electricity-dependent gas pipelines and the supply chains that drive them would cease delivering their “just-in-time” fuel to grid generating stations. And disrupted transportation and communications would halt the diesel fuel production and deliveries required for the emergency generators needed by the power grid, and by all other lifeline infrastructures. These two examples highlight the need for thorough, prearranged cross sector support to infrastructure restoration.

If EMP-compatible Black Sky plans are not available, restoration efforts in these scenarios would be agonizingly slow, precisely when they would be most urgent to sustain and save lives, and to support national continuity and security.



## The Evolving EMP Threat Assessment

### Historical Perspective

In 1962, deep in a cold war with the Soviet Union, the United States conducted “Starfish Prime,” an upper atmosphere nuclear weapon test over a remote region of the Pacific Ocean.<sup>7,8</sup> The test was successful, with one unexpected result: eight hundred miles away there were burned-out streetlights and radio and TV failures in parts of Hawaii, as well as damage to a new communications satellite. Three similar Soviet tests that same year over Kazakhstan caused far greater effects, with power grid generating station failures, underground power line fusing, and failures of 1962-era military hardware -- long before the far more vulnerable and ubiquitous microchips that power today’s world.<sup>9</sup>

The results of these first U.S. and Soviet nuclear EMP tests transformed strategic defense planning throughout the cold war, and EMP was studied and addressed diligently as a military threat for over 50 years. Strategic defense during these decades was focused on nuclear deterrence, with protection of the U.S., both civil and military, derived from investment in Mutually Assured Destruction (MAD), a strategy designed to bring an end to both nations if either were to launch an attack. Secure EMP protection of U.S. “Second Strike” assets, and their command, control and communications systems, was a critical priority for the MAD strategy. EMP protection of the Cheyenne Mountain Command and Control bunker complex is a primary example of this strategy.



### **The EMP Threat Today**

We no longer live in the bipolar geostrategic reality of the U.S.-Soviet Cold War. Today, nations with extreme ideologies or unstable leadership have, or may soon have, small nuclear weapon stockpiles. Nuclear proliferation is an expanding reality of the 21<sup>st</sup> century, and as a result, there is widespread military consensus that the doctrine of Mutually Assured Destruction is no longer an adequate foundation for the security of our nation.

Our vulnerability is particularly acute when dealing with a highly "asymmetric threat" like EMP, capable of giving even a very small adversary or non-state actor a capability that could have a catastrophic impact on the United States. In this regard, EMP has features that make it uniquely dangerous, even among Black Sky hazards.

A successful EMP attack does not require human intelligence or cyber resources, detailed targeting information, access, or other sophisticated capabilities. Modern infrastructure vulnerabilities are well known, and the huge "footprint" of an EMP field means targeting errors of even hundreds of kilometers would have no appreciable impact on a weapon's effectiveness. In addition, today, with just a few (though important) exceptions, little focused investment or planning has been done to mitigate the vulnerability of our lifeline infrastructures to this emerging, extreme threat.

These two unique factors -- no need for specialized knowledge or access to targeted infrastructures; and today's minimal infrastructure EMP protection -- contribute to one of the most dangerous aspects of this threat. Any state or

entity that can buy or hijack a handful of nuclear missiles, or even a single nuclear missile, perhaps launched, as the Congressional EMP Commission warned,<sup>10</sup> from a disguised freighter in the Gulf of Mexico, could mean unprecedented catastrophe for an unprepared nation. As the Commission noted, "EMP is capable of causing catastrophe for the nation," as "one of a small number of threats that has the potential to hold our society seriously at risk, and might result in defeat of our military forces."<sup>11</sup>



B

# RESPONDING TO THE EMP THREAT





The Pentagon's Cheyenne Mountain EMP-protected strategic command facility

## Where are we today?

### Defense and Security Agencies

The Department of Defense (DOD) is already working to harden its strategic infrastructure against EMP. Speaking as head of the North American Aerospace Defense Command (NORAD) and Northern Command, Adm. William Gortney announced new spending of over \$700M to reopen Cheyenne Mountain, the Cold War strategic command facility, citing the growing risk of nuclear EMP attack on America.<sup>12</sup>

**The “shift to the Cheyenne Mountain base in Colorado is designed to safeguard the command's sensitive sensors and servers from a potential electromagnetic pulse (EMP) attack, military officers said.”<sup>13</sup>**

This took place in parallel with a new DOD Defense Instruction, issued in the same time frame, requiring EMP protection to be included as a requirement for all “Mission Critical” facilities.<sup>14</sup>

The Department of Homeland Security (DHS) and other federal agencies have also begun reviewing EMP protection strategies. DHS, for example, according to Congressional Testimony, now advises that all critical infrastructure sectors are at risk from EMP.



**“All critical infrastructure sectors are at risk from EMP,” according to Congressional Testimony from Brandon Wales, DHS Director of Cyber and Infrastructure Analysis. His response, when asked during testimony whether the U.S. [today] could effectively withstand an EMP attack: “Clearly the answer is ‘no.’”<sup>15</sup>**

The United States and its partners abroad also conduct a variety of programs to reduce the likelihood that terrorist groups can acquire the nuclear materials and other components necessary for building such weapons. The Cooperative Threat Reduction (CTR) program, for example, helps secure nuclear materials in the former Soviet Union. While these programs have demonstrated substantial progress in reducing the threat that nuclear materials will be stolen, current estimates assess that, as of January 2012, there were still approximately 1440 tons of highly enriched uranium and around 500 tons of separated plutonium stockpiled globally -- providing a vast array of potential targets for terrorists seeking such materials.

Coupled with increasing proliferation of “nuclear weapon precursor” technology, this has added to security concerns associated with the growing stockpiles of nuclear warheads and missiles in the control of unstable or unfriendly nations.



## **Civilian Infrastructure**

While military facilities and defense systems built EMP protection into their facilities and weapon systems over the decades of the cold war, civilian infrastructure EMP vulnerability is a far more recent concern, initiated by the fading of the MAD strategy, and made urgent by the unprecedented nuclear proliferation of modern times. This emerging civil vulnerability was highlighted first by Congressional EMP Commission reports in 2004 and 2008, followed by a growing number of government studies in the years that followed.

This process continues today, with new studies now beginning in DOE, DHS and the Electric Power Research Institute, and EPRO EMP -- EIS Council's upcoming, peer-reviewed voluntary EMP protection specification. Such new studies may add to our understanding of vulnerabilities and help improve and optimize protection measures. However the key strategies and most of the techniques required for EMP protection are now quite well understood. If we wish, as a nation, to be able to survive Black Sky - level events, we must expand implementation of protective measures and planning for EMP, as for any Black Sky hazard.

At this point, EMP resilience for the U.S. power grid requires systematic, subsector-wide investment and operational planning, coupled with the same, unprecedented, coordinated cross-sector restoration support planning that will be required for all Black Sky-class hazards. Modern societies - and all the resources and services that sustain our lives - are now interconnected on an unprecedented scale. Thoroughly coordinated, cross-sector operational planning is essential if we are to assure national continuity in the aftermath of EMP, or any other Black Sky hazard. The expanding EPRO SECTOR process provides a primary example of such planning.



## **EPRO® SECTOR:**

### **Coordinated Multi-Sector Planning for Black Sky Hazards**

*Whole community collaboration to support critical infrastructure resilience and restoration.*

The starting point for any examination of critical lifeline infrastructure is the Energy Sector, and its two essential components – the Oil and Natural Gas Subsector and the Electricity Subsector. Each of these subsectors has expanded its efforts in resilience investment broadly. Within the Electricity Subsector, specific EMP planning meetings and research efforts have started to take place, and some of the largest power companies are now making systematic investments in EMP protection across different elements of their transmission systems.

These steps represent an excellent foundation for progress. However, far more will need to be done before the sector's resilience and operational planning measures have reached a threshold adequate to cope with an EMP attack on the nation. Interdependencies affecting preparedness for any Black Sky hazard will also need to be addressed.

Of course, the Energy Sector is only one of many lifeline infrastructures that will need to build Black Sky resilience and restoration support planning. And as that sector's plans mature, along with those of other infrastructure sectors and those of their government, NGO and corporate partners, cross-sector interdependencies and restoration support must be addressed if the nation is to have an effective, interconnected "backup system" that can effectively sustain the population and support restoration efforts for an EMP attack or any Black Sky hazard scenario.

This planning, hosted by EIS Council as part of its EPRO SECTOR process, is now expanding rapidly, with the active and diligent involvement of leaders from many of the most critical lifeline infrastructure sectors. Operational managers from the



electricity and oil and natural gas subsectors are now beginning to work together with colleagues from the water sector, as well as state and federal emergency managers, mass-care NGOs and regulatory agencies, building detailed Playbooks that define the internal and cross-sector measures each will need to put in place, for the nation to be able to effectively survive an EMP strike or any other Black Sky hazard.

EMP, however, is a special case among the full set of Black Sky hazards. As the least well-known "emerging threat" in this class of uniquely severe hazards, finding definitive, comprehensive planning documents to guide power companies' EMP protection planning has been quite difficult. And with no examples yet available of comprehensive grid-wide EMP protection strategies, experience applicable to all elements of modern power grids has been lacking.

To address this need, EIS Council is assembling a new publication in the EPRO Handbook Series -- EPRO EMP -- designed to serve as a detailed, voluntary EMP specification, adequate for power system engineers to use to begin planning and implementing EMP protection for their companies. Developed by the only team in the world that combines military and civilian EMP protection experience with current work on the development of the world's first full-grid EMP protection plan, EPRO EMP will be completed in 2017, and made available to U.S. and allied nations' power companies and related stakeholders.

EIS Council is proud of its critical role in hosting this coordinated process, and helping facilitate the increasingly detailed planning that is critical for sustaining and restoring lifeline infrastructures in any Black Sky hazard scenario.

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