The Geospatial Dimensions of Critical Infrastructure and Emergency Response

White Paper Series

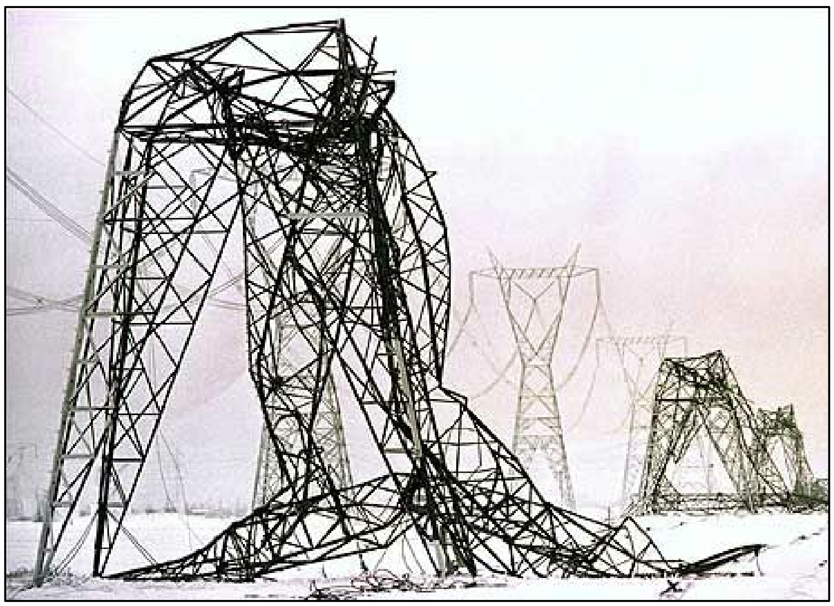
Electric Sector Infrastructure Interdependencies

GEOSPATIAL INFORMATION & TECHNOLOGY ASSOCIATION

INTRODUCTION

The 2009 edition of "The Report Card for America's Infrastructure" was published by the American Society of Civil Engineers (ASCE) in late January, its release date accelerated to try to influence the debate over the $825 billion economic stimulus bill then being negotiated by the Obama administration and Congress. It should be no surprise to anyone that the major infrastructure assets in the fifteen categories examined fared no better than they did in the 2005 Report Card.

As in previous versions, the report included the critical infrastructure areas of energy, water, wastewater, bridges, dams, roads and transit, and several other areas. For the first time, levees were considered as a separate infrastructure category. Security, which had been treated separately in the 2005 report, is now being viewed in the context of resilience – the ability to withstand and recover from natural and man-made hazards. As such, resilience has been integrated into the grading within each category.



Since the last report, while some categories showed improvement, the overall status of the Nation's major infrastructure assets was again rated a "D." The bill for remediation of this problem, however, grew from $1.6 trillion to $2.2 trillion – an increase of some $600 billion. Overall, the energy sector which includes electric utilities received a grade of "D+" in the 2009 Report Card.

Electric utilities in the US and Canada are at a critical point that requires substantial investment in deteriorating infrastructure, including generation facilities and transmission and distribution systems. Further, transmission and distribution systems are becoming adversely impacted due to the rapid growth in electricity demand. This resulting congestion prohibits utilities from making planned outages to perform the necessary maintenance, the lack of which will lead to more failures in the grid in the coming years. Since 1990, electricity demand has increased by about 25% while new construction of transmission facilities *decreased* by nearly 30 percent. As a result, substantial investments in generation, transmission, and distribution are needed over the next two decades to improve electric utility capacity and infrastructure resilience. These investments must leverage new advanced technologies that will improve the existing electric system and ultimately revolutionize the electric grid, including the expanded use of geospatial technology.

The Geospatial Information and Technology Association (GITA) is extremely concerned about the current status of the Nation's infrastructure and ways to begin to address this increasingly serious problem. There are serious social, political and economic development considerations that impact our ability to make progress in this area — and severe ramifications of our failure to do so. GITA defines infrastructure as, "all fundamental services, activities, and operations that sustain our communities and way of life."

GITA is fully committed to advancing the use of geospatial technology to address our infrastructure problems. GITA's members and constituents — professionals in the electric, water/wastewater, gas and oil pipelines, telecommunications and local, state and federal government sectors — are using geospatial solutions on a daily basis to do just that.

In late 2008, the GITA Research Committee undertook an effort to address the "Geospatial Dimensions of Critical Infrastructure Protection and Emergency Response." The first step was to promote better understanding and communication about how a failure or an event in one infrastructure sector may affect assets in others – how all infrastructure is ultimately connected. A seminal White Paper on **"Interdependencies of Infrastructure"** was developed to form the basis for further exploration of this concept. The next phase of this project is to delve into each of the infrastructure sectors represented by GITA's members and constituents in order to define and discuss these important connections, how these interdependencies might influence the ways in which we respond to our infrastructure crisis, and the emerging key role of geospatial technology in protecting our critical infrastructure and improving emergency response.

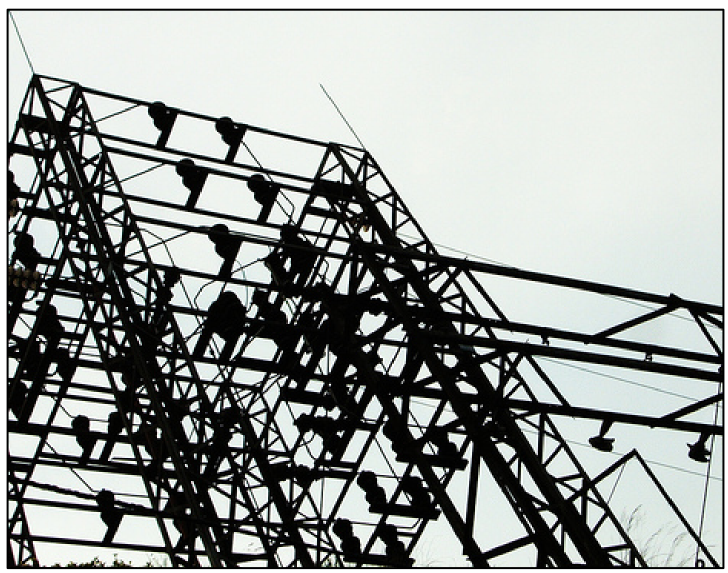
This White Paper on "Electric Sector Infrastructure Interdependencies," is one of several sector-specific views of the importance of understanding how our infrastructure is connected.

CRITICAL INFRASTRUCTURE PROTECTION

In addition to improving the condition of their key infrastructure assets, electric utilities are examining their security practices, performing vulnerability assessments, improving resilience, and making appropriate enhancements to their security programs. Such enhancements include supplementing current emergency plans with terrorist risk elements, strengthening physical barriers, tightening control access, adjusting frequency of patrols (both physically and virtually), and confirming response and recovery actions with local law enforcement and emergency management officials.

In some sense, the term "Critical Infrastructure Protection" is a misnomer. Since disasters are, from the point of view of critical infrastructure, inherently random in nature, not all critical electric infrastructure components can be protected. No fail-safe methods, technologies or approaches exist that can eliminate all conceivable risk to critical infrastructure. Natural events will still occur, accidents will still happen and committed terrorists will still succeed. Even with continuous monitoring and surveillance, complete threat interdiction remains an elusive and unrealistic goal.

Cross-sector partnerships that are aligned with critical infrastructure protection capabilities and are coordinated with federal, state, and local emergency response protocols, can advance the prevention, protection, and especially the response to, and recovery from, both terrorist and natural disasters. Currently, these partnerships are not widespread, particularly regarding the engagement of the electric sector. Under the National Infrastructure Protection Plan (NIPP), the electric sector is one of 18 federally identified critical infrastructures and key resources for the nation.



The data substantiating the need to address electric sector interdependency is overwhelming as there are more than 3,100 electric utilities in the United States. Among them are 213 stockholder-owned utilities that provide power to over 70% of all electric customers; approximately 2,000 municipal or state owned utilities that provide power to about 15% of the customers; and over 900 electric cooperatives providing power to about 12% of the customers. Combined, these utilities operate over 150,000 miles of high-voltage electric transmission lines.

These electric utilities are parts of a highly connected and interdependent infrastructure that provides vital services and economic security for a community, region, and the nation. Additionally they provide services essential to other infrastructure sectors during emergency response efforts, including providing power to pump water for fire protection as well as dozens of critical services essential to the recovery of areas impacted by natural disasters or terrorist events.

While electric utilities have made vast improvements in the area of security and emergency response since the events of September 11, 2001, many utilities still lack coherent local and regional partnerships across multiple sectors in order to prepare for, and effectively respond to, man-made threats and natural disasters. Building on accomplishments from both inside and outside the electric sector, GITA has been providing information to electric utility personnel, as well as key stakeholders in other sectors, on the critical nature of electric utility interdependencies.

Although protection of critical electric infrastructure remains an impossible ambition, emergency managers can adopt strategies for disaster management to better reduce the impact of natural or man made disasters. These strategies typically include pre-disaster preparedness, emergency response, disaster recovery and long-term mitigation activities. The goals of Critical Infrastructure Protection are more realistically set to minimize consequences of an event or disaster through timely notification, information-driven responses, well prepared first responders and citizens, and pre-planned and rehearsed contingency activities. Private sector, Federal, State and local officials have different roles in disaster response, homeland security and terrorism response situations.

ELECTRIC SECTOR CRITICAL INFRASTRUCTURE INTERDEPENDENCIES

Electric infrastructure assets have a number of interdependencies with other infrastructures that must be considered when identifying and classifying critical infrastructure, developing response plans, and in addressing other issues of security and protection. Figure 1 depicts the interconnectedness of the critical electric infrastructure with gas and oil pipeline, water, wastewater, communications, and transportation infrastructures, as well as the emergency response community.

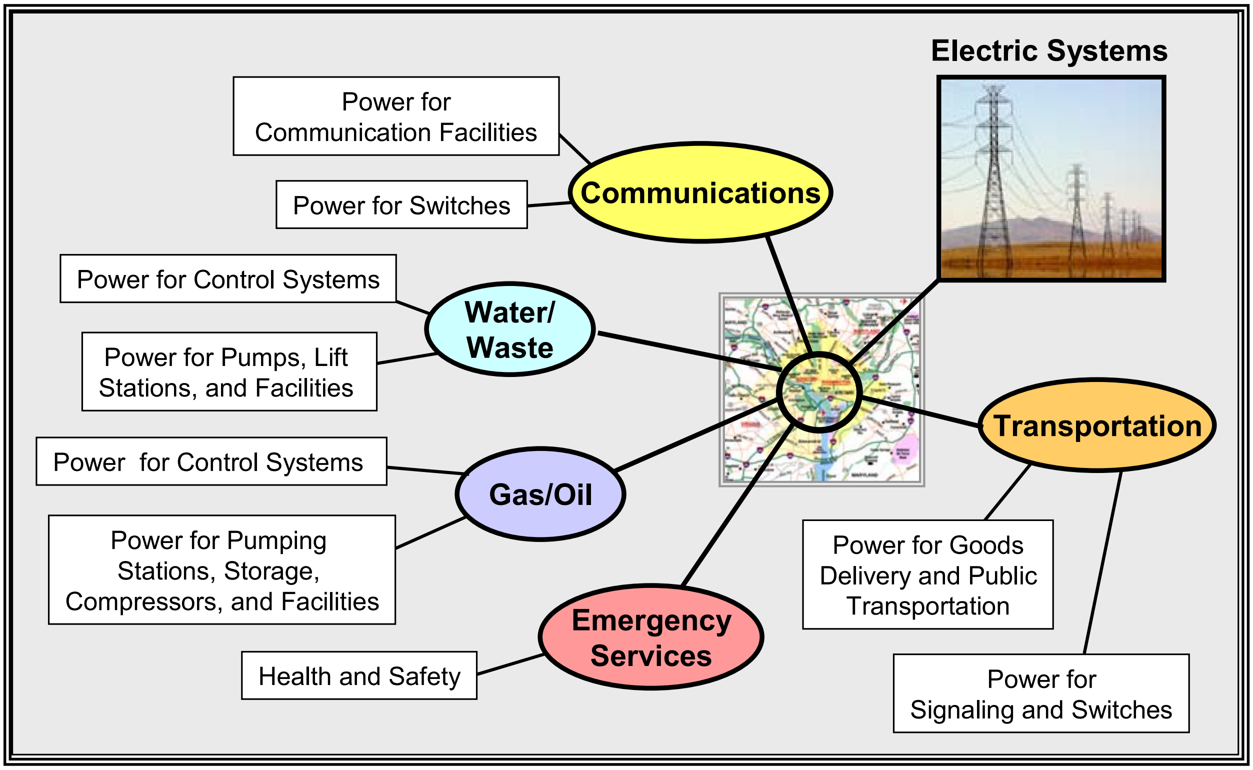


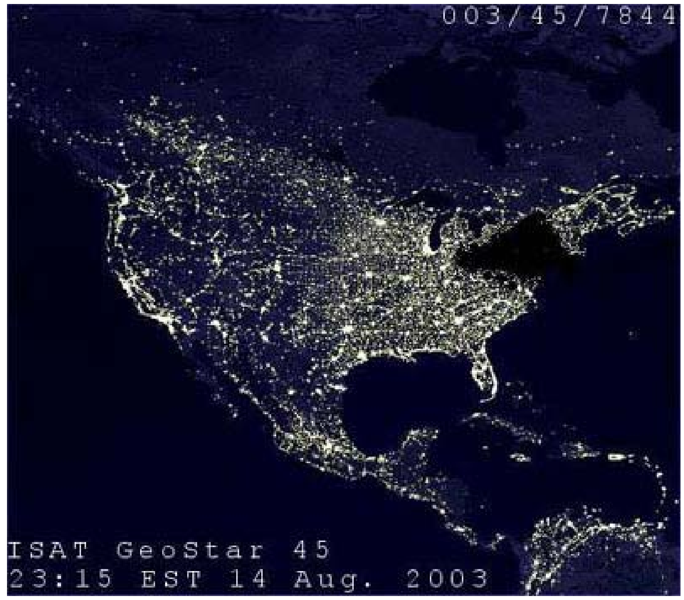
Figure 1: Electric Sector Infrastructure and Interdependencies

Understanding the interdependencies among critical infrastructures is essential to providing for the continuity, sustainability, and resiliency of each infrastructure component.

Many electric utilities are generally prepared for local and regional responses; however, the national electric grid as a whole lacks a significant degree of resilience should a much broader response be required. Future investments in the system are needed to improve system robustness, redundancy, and rapid recovery. Additionally, new technologies and behavioral changes focused on reduction and increased efficiency are necessary. True system resilience will require a national effort to modernize the electric grid to enhance security and the reliability of the energy infrastructure and facilitate recovery from disruptions to energy supply, from both natural and man-made hazards.

The Blackout of 2003

The public's reliance on a constant supply of electricity is such that uninterrupted service is generally expected. While occasional outages receive coverage in the media, the extended impact from a significant failure of the electric system, such as the 2003 blackout in the northeastern U.S., was never more evident than on August 14. A massive power fluctuation in the power grid caused a widespread power outage that occurred throughout parts of the Northeastern and Midwestern US, and Ontario, Canada. According to US and Canadian government analysis of the blackout, more than 508 generating units at 265 power plants shut down during the outage. The blackout affected an estimated 45 million people in the U.S. and 10 million people in Ontario, Canada. Tens of thousands of businesses were impacted economically. Some essential services remained in operation in most of these areas, although backup generation systems in many cities were not up to the task. Emergency responders were greatly affected because wireless communications experienced significant service disruptions as cellular transmission towers were overloaded with the sudden increase in volume of calls. The following provides examples of the interconnectedness of the electric, water, transportation, and communication infrastructures during the blackout.



Energy Sector: With the power fluctuations on the grid, power plants across the region automatically went into "safe mode" to prevent damage in the case of an overload. This put much of the nuclear power normally available offline until those plants could be slowly taken out of "safe mode". In the meantime, all available hydro-electric and coal/gas fired plants were brought online, bringing some electrical power to the areas immediately surrounding the plants the following day. Homes, businesses, and manufacturing in the affected area and in nearby areas were requested to limit power usage until the grid was back to full power.

Water Sector: Many urban and rural areas lost water service due to lost water pressure because pumps didn't have power. This loss of pressure caused contamination of some of the water supply. Million of residents from Detroit to Toronto were under a “boil water advisory.” Cleveland and New York had sewage spills into waterways, requiring beach closures. Newark, New Jersey and other northern cities had major sewage spills into the Passaic and Hackensack Rivers, which flow directly to the Atlantic Ocean.

Many other smaller municipal sewer agencies lost power to their wastewater pumping and treatment facilities, causing raw waste to be dumped into area rivers.

Transportation Sector: Amtrak's Northeast Corridor railroad service was stopped north of Philadelphia and all trains running into and out of New York City were shut down, initially including the Long Island Railroad and the Metro-North Railroad. Both were able to establish a nominal "all-diesel" service by the following day. Canada's VIA Rail, which services Toronto and Montreal, suffered service delays. Passenger screenings at affected airports ceased and regional airports were shut down for this reason. In New York, flights were cancelled even after power had been restored to the airports because of difficulties accessing electronic-ticket information. At one point a seven hour wait developed for trucks crossing the Ambassador Bridge between Detroit and Windsor due to the lack of electronic border check systems. Freeway congestion in affected areas affected the "just-in-time" supply systems for hundreds of manufactures in the Northeast.

Communication Sector: Wireless communication devices were disrupted. This was mainly due to the loss of backup power at the cellular sites where generators ran out of fuel or cell phone batteries ran out of charge. Wired telephone lines continued to work, although some systems were overwhelmed by the volume of traffic, and millions of home users had only cordless telephones depending on house current. In addition, cable television systems were disabled, and areas that had power restored could not receive information until power was restored to the cable provider. Those who relied on the Internet were similarly disconnected from their news source for the duration of the blackout.

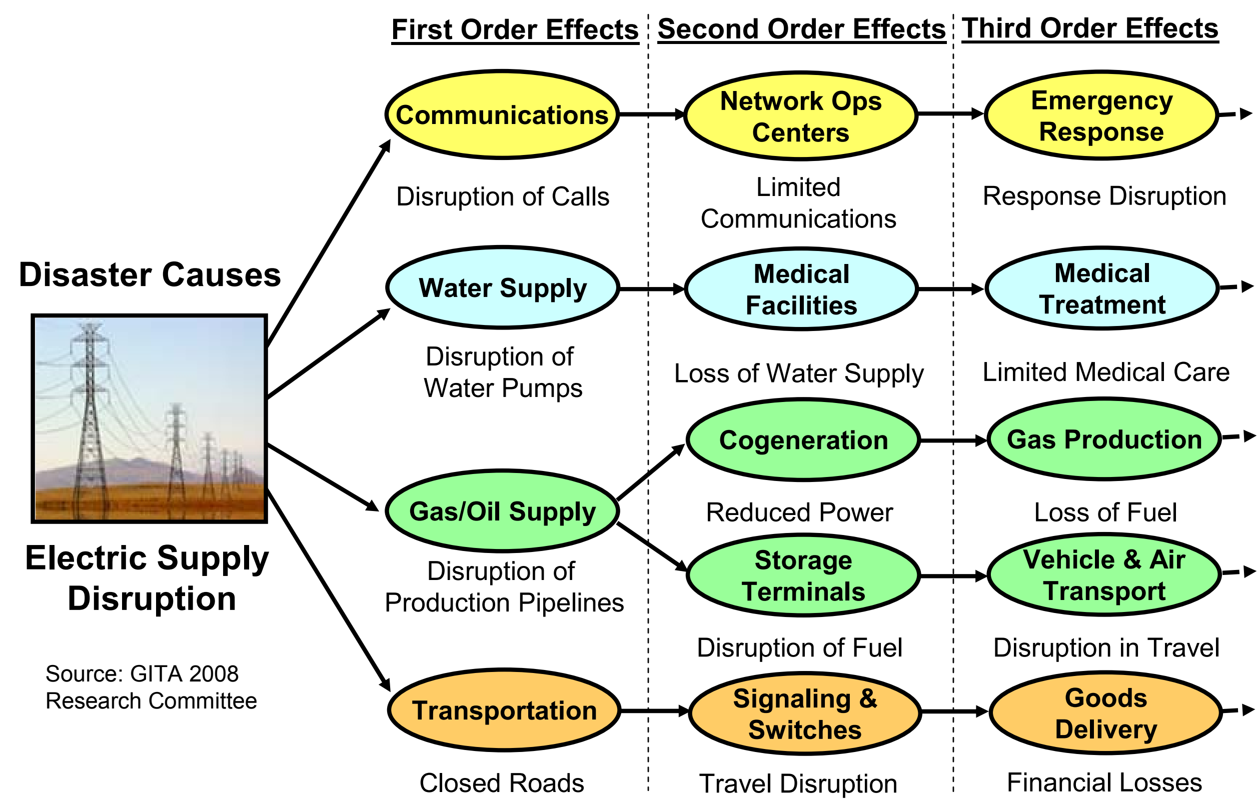
CRITICAL INFRASTRUCTURE CASCADING CONSEQUENCES

While the interdependencies within an individual infrastructure such as electric transmission and distribution systems are becoming more understood, the influence or impact that one infrastructure may have on another is the focus of interest in interdependencies and effects modeling. The key effects to model and understand are the chains of influence that cross multiple infrastructure sectors and precipitate potentially unforeseen effects. As depicted in Figure 4, these chains are composed of multiple interdependency types. They constitute the connections between infrastructure nodes. These particular connections represent the cascading consequence of the effects of an emergency in specific infrastructure areas, such as the 2003 North

American blackout that affected nearly every economic entity and household in the Northeast US and Ontario.

The massive power fluctuation and resulting blackout was the result of three different types of failures that can affect interdependent infrastructures. First, a *cascading failure* is a disruption in which one infrastructure causes a disruption in a second. (e.g., the loss of power impacting water service and pressure). The second type, an *escalating failure*, occurs when a disruption in one infrastructure exacerbates an independent disruption of a second infrastructure (e.g., the time for restoration of a failure of power transmission lines increases because of a bridge collapse from a barge accident that prevents repair crews from reaching the failed infrastructure). The third type is known as a *common cause failure,* in which a disruption takes place with two or more infrastructures at the same time as the result of a common cause (e.g., environmental condition, such as an ice or snowstorm).

Figure 4: Critical Infrastructure Cascading Consequences



In short, it is impossible to adequately analyze or understand the behavior of a given infrastructure in isolation from the environment or other infrastructures. Multiple interconnected infrastructures and their interdependencies must be considered in a holistic manner. This will allow emergency planners and responders to better understand, and therefore be better able to address, the cascading consequences associated with critical infrastructure. Because of its inherent capability to define and analyze the spatial attributes of virtually every infrastructure asset, geospatial technology is ideally suited to identifying these interdependencies and then modeling effective responses.

SUMMARY

It is important to recognize that our infrastructure assets are inexorably tied together in myriad ways in a vast network that provides the foundation for our quality of life, economic well being and overall security. An understanding of these relationships, or interdependencies, is crucial to effective response, mitigation and recovery in times of emergencies caused by natural occurrences, or those resulting from intentional or accidental human activity.

This White Paper entitled "Electric Sector Infrastructure Interdependencies" is intended to convey specific interdependencies from the perspective of one of the primary industries that comprise GITA's membership and various constituencies – the electric sector. Additional White Papers in the series address the oil and gas oil pipeline, water and wastewater, telecommunications, and transportation sectors. Governmental (local, state and federal) relationships are addressed in each sector where applicable.

The Geospatial Information & Technology Association is focused upon infrastructure in the belief that geospatial technology is a key tool in addressing the serious challenges of infrastructure degradation, critical infrastructure protection and emergency response. For more information on the "Geospatial Dimensions of Critical Infrastructure and Emergency Response White Paper Series", as well as related initiatives, please contact GITA, or visit the GITA website at www.gita.org.

About the Geospatial Information & Technology Association

The Geospatial Information & Technology Association (GITA) is the professional association and leading advocate for anyone using geospatial technology to help operate, maintain, and protect the infrastructure, which includes organizations such as utilities, telecommunication companies, and the public sector. Through industry leading conferences—along with research initiatives, chapters, membership, and other programs—GITA provides education and professional best practices.

Acknowledgement

The author, David DiSera, and the members of GITA's Industry Trends Advisory Group gratefully acknowledge the support provided by the Geospatial Information & Technology Association for this research. Any opinions, findings, conclusions, and recommendations expressed in this material are those of the author and do not necessarily reflect those of the Geospatial Information & Technology Association.

Geospatial Information & Technology Association
14456 East Evans Avenue
Aurora, CO 80014

GEOSPATIAL INFORMATION &
TECHNOLOGY ASSOCIATION