ELECTRIC INFRASTRUCTURE PROTECTION

Executive Summary

E-PRO® HANDBOOK III

Black Sky Cross Sector Coordination and Communication

Electric Infrastructure Protection (EPRO®) **Handbook III**

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EIS COUNCIL

The ELECTRIC INFRASTRUCTURE PROTECTION (EPRO®) HANDBOOK® SERIES

A peer-reviewed, research-based resource, examining opportunities for expanding the resilience of lifeline utilities and their government and NGO sector partners to address severe, Black Sky hazards.

Executive Summary

Hurricane Irma hits Naples, Florida. (AP Photo)

INTRODUCTION

The electrification of our planet has become the foundation for the technological progress that is shaping the 21st century. As electricity has become more widely available and reliable, it has transformed modern society and made possible today's unprecedented network of interconnected infrastructure systems, from food and water distribution to the internet and beyond. The "electrification of everything" has also enabled the rise of today's megacities and the continued growth of the global economy.

However, this tightening web of connectivity also makes infrastructure sectors extraordinarily dependent on each other and vulnerable to cascading failures. "Black Sky" events – subcontinent scale power outages – represent a particularly serious risk. A broad array of natural and manmade hazards could cause such catastrophic blackouts, including extreme earthquakes, attacks by Electromagnetic Pulse (EMP) weapons, and coordinated cyber and physical attacks against critical grid components.

The tightening connectivity between infrastructure sectors has transformed society but creates unprecedented vulnerabilities.

On a bounded scale, the power outage that Hurricane Maria inflicted on Puerto Rico in September 2017 exemplifies such an event, showing how failures can ripple across a broad array of electricity-dependent infrastructure. Water utilities, communications systems, transportation infrastructure, and most other resources and services rapidly broke down when they lost power.

This escalating infrastructure connectivity – and the associated cross-sector interdependencies – have made Black Sky events a new and particularly dangerous class of risks to modern society, characterized by circular, mutually reinforcing breakdowns between critical systems. In the event of a catastrophic blackout, in order to restore power, electric companies rely on communications, transportation, and other infrastructure systems to support repair operations, and sustain their personnel. But those same infrastructure systems depend on electricity to function. With nearly all infrastructures now hyperconnected, no single system – including the electric subsector – can make progress with restoration without at least minimal functionality of most of the others, creating a dilemma for societal continuity following such a blackout.

> Without carefully integrated, multi-sector planning, the breakdown of systems vital to support power restoration would make it impossible for power companies to proceed with power restoration, undercutting any hope of Black Sky restoration and recovery.

Strengthening resilience against such cascading failures has, therefore, become a national imperative, especially as disparate sectors become ever-more tightly coupled and, as a system, ever-more fragile.

This Handbook proposes new approaches that could address this concern by strengthening both cross-sector planning and real time cross sector coordination, building on the progress being made by infrastructure owners and operators and their public sector partners.

In particular, it will be essential go above and beyond efforts to bolster the resilience of individual infrastructure sectors. Within each sector, system owners and operators are hardening their own assets against manmade and natural hazards. Their initiatives are valuable and should be scaled up for Black Sky events.

However, given the deepening interdependencies between sectors, and the intensifying risks of cascading and mutually reinforcing failures, it is also essential to take two further steps:

1. **Black Sky Multi-Sector Preplanned and Real Time Coordination:** Develop cross-sector plans and collaborative mechanisms for industry, government and mass care NGOs to jointly preplan and, in real time, coordinate assets and efforts essential for population sustainment and for restoration of essential infrastructures, resources and services.
2. **Black Sky Multi-Sector Emergency Communication and Coordination Support:** Deploy a survivable, widely-distributed communications and coordination system (including hardware and software) that can provide a foundation for such a coordination effort, enabling the private sector, government agencies, and non-governmental organizations to prioritize and conduct cross-sector sustainment and restoration operations.

The chapters that follow provide recommendations to meet these requirements. This EPRO Handbook volume also examines the key risks that rising interdependencies create for critical infrastructure resilience, and analyzes how recent private sector and government initiatives (including the issuance of the Power Outage Incident Annex)[1] can be leveraged to build preparedness for Black Sky events.

1 Department of Homeland Security, Power Outage Incident Annex to the Response and Recovery Federal Interagency Operational Plans: Managing the Cascading Impacts from a Long-Term Power Outage, June 2017.

Black Sky Events: Maria and Beyond

On September 20, 2017, Hurricane Maria inflicted Black Sky levels of disruption on Puerto Rico. Power outages extended for more than a month over most of the Commonwealth, creating cascading and mutually reinforcing failures across all critical infrastructure sectors.

Of course, the area devastated by Maria was much smaller than would be disrupted by an EMP attack or other Black Sky hazard in the continental United States. And, particularly critical, the largest cities of Puerto Rico are just a few percent of the size of typical U.S. megacities, with all the implications that holds for both access into cities and for distribution of critical supplies.

Maria is also atypical of Black Sky events in another respect: the hurricane left untouched the mainland's vast disaster response system. A Black Sky event spanning multiple U.S. regions will disrupt the infrastructure on which that response system depends, and will create immense challenges for prioritizing the sustainment and restoration of critical services, as well as the resupply of fuel for emergency generators and other essential resources.

> A Black Sky event across multiple U.S. regions will disrupt the infrastructure on which the American disaster response system depends, and create immense challenges for sustaining and restoring critical services.

Nevertheless, while occurring on a smaller scale, Puerto Rico's tragic experience with Maria offers useful insights into the cross-sector failures that Black Sky events will create. Those failures also help illuminate the requirements for strengthening infrastructure resilience that provide the focus of this volume.

Hurricane Maria exemplifies the way in which Black Sky hazards will cause interdependent sectors to collapse at the same time. Due to direct damage from wind, flooding and other weather effects, electricity transmission and distribution systems, cellphone towers, and other infrastructure quickly failed. So, of course, did the water systems and other sectors dependent on the flow of electricity. Even the emergency managers leading the response to Maria were forced to evacuate the buildings where they had taken shelter. "Everything collapsed," said Héctor Pesquera, the Puerto Rico governor's director of safety and public protection. “Everything collapsed simultaneously.”[2] Future Black Sky events in the continental United States will create such cross-sector devastation on a much larger geographic scale.

Maria also highlights how cross-sector failures will impede the restoration of service critical to saving and sustaining lives. For example, breakdowns in the oil and natural gas (ONG) subsector, including in the distribution of diesel and other liquid fuels, produced many such delays. Hundreds of containers of perishable food and medicine were stuck in ports because trucking systems lacked fuel to operate.[3] Diesel for emergency power generators at hospitals, supermarkets and other facilities quickly ran out, and – due to the lack of electricity for pumps and other key fuel resupply systems – could not be replenished for weeks, even with extensive help from the US mainland.[4]

As a primary lesson-learned, Maria helps illustrate the critical need to build both organizational / structural mechanisms and hardware support tooling that can provide for cross-sector coordination against much larger Black Sky events.

2 Arelis Hernández, Dan Lamothe and Joel Achenbach, “When Hurricane Maria hit Puerto Rico, ‘everything collapsed simultaneously,’” The Washington Post, October 2, 2017, https://www.washingtonpost.com/national/when-hurricane-maria-hit-puerto-rico-everything-collapsed-simultaneously/2017/10/02/a945dfa4-a79c-11e7-850e-2bdd1236be5d_story.html?utm_term=.464f5e7490c8.

3 Dawn Giel, Contessa Brewer and Lori Ann LaRocco, “Puerto Rico, short on fuel, cannot deliver food and medicine to the victims of Hurricane Maria,” CNBC, September 28, 2017, https://www.cnbc.com/2017/09/28/puerto-ricos-fuel-supply-breaks-down-in-the-wake-of-marias-devastation.html.

4 Dawn Giel, Contessa Brewer and Lori Ann LaRocco, “Puerto Rico, short on fuel, cannot deliver food and medicine to the victims of Hurricane Maria,” CNBC, September 28, 2017, https://www.cnbc.com/2017/09/28/puerto-ricos-fuel-supply-breaks-down-in-the-wake-of-marias-devastation.html.

Especially important:

Infrastructure owners and operators, government agencies, and non-governmental organizations will require collaborative decision-making mechanisms.

Maria inflicted such extensive damage on Puerto Rico's infrastructure that it was extraordinarily difficult to sustain or restore essential services. Sustaining or rapidly restoring these services in multi-region Black Sky events will present still greater challenges. A growing number of infrastructure owners and operators are building Black Sky playbooks to help meet these challenges, and are specifying the support they will need from other sectors to help sustain critical functions and prioritize restoration operations.

However, future Black Sky events will also require cross-sector collaboration on a nationwide scale. Given the overwhelming destruction that such events will create, as well as the scarcity of resources to fix or replace key infrastructure components, difficult decisions will need to be made about the order in which specific sustainment and restoration operations should go forward. And with the supply chains that sustain all infrastructures, resources and services today spanning many regions, even local restoration and population sustainment efforts will require such national scale coordination.

Individual infrastructure owners and operators are best positioned to determine their own priorities for assistance. However, in wide area Black Sky events, industry leaders will need to help integrate sustainment and restoration priorities across virtually all sectors to inform collaborative response operations throughout major portions of the United States. Doing so will require: 1) The widely interconnected emergency communications, situational awareness and decision support mechanisms, in addition to the underlying prioritization criteria, necessary to support population sustainment and multi-sector coordination; and 2) Collaborative bodies with representation of all the sectors essential for responding to Black Sky events, in which industry, government and NGO leaders can set operational priorities and help ensure their implementation.

Industry leaders will need to help integrate sustainment and restoration priorities across virtually all sectors in Black Sky events.

As an integral part of such collaborative bodies, deep engagement with emergency managers will be necessary to effectively integrate these cross-sector operations across all aspects of Federal, state, local, tribal and territorial (SLTT) Black Sky response and recovery efforts. Close collaboration will also be needed with the NGOs that will provide mass care and other essential services in Black Sky events. The National Response Framework (NRF) provides the ideal foundation on which to build such public-private collaboration. However, enormous gaps remain in the NRF for guiding cross-sector support. This volume proposes new strategies and collaborative structures to fill them.

Survivable communication and coordination systems are of core importance for infrastructure sustainment and restoration.

Brock Long, Administrator of the Federal Emergency Management Agency (FEMA), notes that Hurricane Maria's near-total disruption of communications in Puerto Rico has implications for disaster preparedness for the United States as a whole. He emphasizes that "we basically just went through a complete and total communication blackout for an island and it creates a lot of panic, a lot of misunderstanding, a lot of misinformation, and that was incredibly frustrating. So I think we have a lot of work to do for survivable [communications]." In particular, he argues that because "we become more and more vulnerable every day as we go to digital networks," having communications systems "designed to handle all hazards" is of paramount importance to prevent public panic and manage response operations.[5]

Installing an antenna on a communication tower in Puerto Rico (Source: FEMA 11/11/2017)

None of the cross-sector collaboration essential for Black Sky events will go forward unless a survivable, widely-distributed communications and coordination system is available to enable and support real-time decisions to

5 Brock Long, Testimony Before the U.S. House of Representatives Committee on Transportation and Infrastructure, November 2, 2017, https://www.hsgac.senate.gov/hearings/2017-hurricane-season-oversight-of-the-federal-response.

prioritize and help conduct such operations. Development of a prototype of such a system – the Black Sky Emergency Communications and Coordination System (BSX™) – is already underway. This Handbook examines the key features of BSX™, the user-based analysis that underlies its design, and how the system can best evolve to meet the requirements of Black Sky events.

Black Sky Hazards: Objectives, Key Questions, and Integrated, Systems Engineering-Based Planning

Objectives

Building preparedness against Black Sky events will require accelerated efforts focused on three essential objectives:

1. Accurately model the increasing interdependence of infrastructure sectors;
2. Define and invest in the essential resilience resources and create the cross-sector plans and capabilities needed to:
    - Support multisector restoration for vital facilities and functions
    - Sustain the population, and especially shelter in place, as restoration proceeds
3. Deploy the survivable communication and coordination systems essential for both intra-sector and cross-sector operations.

If such objectives are to be met for both natural and manmade hazards, efforts must take into account the risk that adversaries will:

A) Design their attacks to exploit sector interdependencies, maximizing the cascading and mutually reinforcing infrastructure failures that they create.

B) Once the attack is underway, seek to disrupt the cross-sector operations we perform to sustain and restore critical services, and cripple the communications and coordination systems on which those operations depend.

Fundamental questions raised by Black Sky hazards

As in any enterprise, the first step must always be to ask – and answer – critical underlying questions that point toward all the effort that will follow. While seemingly simple, explicitly putting such basic questions on the table can be enormously helpful in guiding efforts.

> Without adequate preparation, a Black Sky event striking the continental U.S. would end societal continuity.

This is particularly true of Black Sky hazards, where the underlying question can help decision makers understand the societal consequences of the question, and the implications of the answer.

For Black Sky events, this becomes a fundamental, existential question:

"Do the United States and allied nations wish to be prepared to survive Black Sky outages?"

And, if this question is to have practical meaning, it must be accompanied by a close corollary:

"Should we challenge ourselves to develop cost effective approaches to address this need?"

Integrated, Systems Engineering-based planning for Black Sky hazards

If the answers to these two interrelated questions are both "yes," and if such answers are to be meaningful, there are several implications for the work that lies ahead. In particular, carefully coordinated, integrated, sector-by-sector resilience investment and planning to address Black Sky scenarios will be essential. How can such integrated, multi-sector planning be framed?

Rigorous, systems engineering-based planning provides an excellent template for such a process, ensuring that each segment of any enterprise focuses their efforts on a mission compatible with the overall enterprise, and then defines the internal requirements – and the external requirements – their segment will need to meet to accomplish this mission.

For societal infrastructures and other key resource and service categories, this may be characterized as responses to the following questions:

1. **Black Sky sector missions**
   In such catastrophic events, what essential services, resources or other support should each sector be prepared to provide to partner sectors and the populations they serve?

2. **Black Sky sector-specific "internal" requirements**
   What cost-effective operational planning and specific resilience measures will be needed by each infrastructure sector to strengthen its own resilience against Black Sky hazards?

3. **Black Sky sector-specific "external" requirements for assistance**
   What support, resources, or new externally controlled policy frameworks will each sector require from its cross-sector partners, as well as from government agencies and non-governmental organizations (NGOs), to make its own efforts meaningful and effective?

Black sky resources

A growing number of infrastructure owners and operators and their resilience partners are now addressing these issues, especially in the Energy, Water and Emergency Management sectors. Their development of Black Sky Playbooks and related work has been supported by the EPRO SECTOR Project,[6] by the EARTH EX and Black Sky Exercise Project, and by EPRO Handbooks I and II. For the Handbooks, specific areas of support include:

- **EPRO Handbook I**
  recommended an array of options to scale up infrastructure protection and power restoration operations to help utilities and their partners reduce the scope and duration of outages that severe hazards can cause.

6 For more information, please visit http://www.eiscouncil.org/EPro

- **EPRO Handbook II** - Volume I
  examined opportunities to strengthen the resilience of fuel supplies for power generation in Black Sky events, especially natural gas. The growing interdependencies between the energy subsectors magnify the potential for cascading, mutually-reinforcing failures, which increase the risk of catastrophic power outages.

- **EPRO Handbook II** - Volume II
  provided recommendations on strengthening the resilience of the water sector against Black Sky outages. The ability of water and wastewater systems to sustain emergency operations in a Black Sky event will offer a particularly valuable means to avert catastrophic threats to societal continuity and human life.

The challenge ahead: Key questions for multi-sector collaboration, communication and coordination in Black Sky events

With Black Sky planning now beginning to move forward in multiple sectors, the next, urgent step is to begin planning for the coordination frameworks and tools that will be essential to tie all such effort together, both before an event, and during the complex response after it occurs. As a first step, such efforts must respond to several fundamental questions:

a. What multi-sector planning and guidance, both in advance and in real time, can provide the requisite level of collaboration to sustain (or rapidly restore) the very most essential infrastructure systems and services?

b. How can such collaboration be structured in a way that is both consistent with Federalism and the U.S. Constitution, and reflect the primary responsibility of infrastructure owners and operators for the resilience of their systems?

c. How should the Unites States and partner nations develop and deploy communication and coordination systems to support multi-sector operations that are widely distributed, interoperable, and can operate in Black Sky events?

EPRO Handbook III addresses these questions and proposes options to strengthen multi-sector resilience.

Chapter I of the Handbook examines the explosive growth in infrastructure interdependencies, and how natural and manmade Black Sky hazards could produce crippling failures across and between infrastructure sectors. Based on those vulnerabilities, the chapter proposes criteria to prioritize cross-sector support operations in Black Sky events. The chapter then recommends measures to help such operations go forward through collaboration: 1) between infrastructure owners and operators; 2) between government actors operating in sector or agency silos; and 3) between sector leaders and their government and NGO counterparts.

Chapter II analyzes the requirements that multi-sector operations will entail for communications and coordination systems, and for decision support for industry, government and NGO leaders. Chapter II also describes how the BSX system is evolving to meet these needs, and identifies next steps for the buildout of the system.

CROSS-SECTOR COORDINATION CHALLENGES, AND STRATEGIES AND STRUCTURES FOR COLLABORATION

1. **Economic Challenge:** Powerful economic forces are driving the rise of cross-sector interdependencies, creating new sources of fragility for which the United States is utterly unprepared

Compelling economic incentives are accelerating just-in-time inventory management, consolidation and reduction of excess capacity in distribution systems and concentration of critical facilities. Halting these shifts would harm U.S. competitiveness and be wholly impractical. It is nonetheless essential to identify and mitigate the new vulnerabilities that these trends are creating for Black Sky response operations, including the delivery of food, fuel, chemicals for water treatment and other vital supplies.

> The United States is utterly unprepared to account for new sources of fragility created by cross-sector interdependencies.

Recommendation: Transform cross-sector resilience into a prime focus for private sector, government, and NGO planning

The electrification of everything, the rise of the Internet of Things, and the rise of system autonomy are outstripping current efforts to understand and mitigate cross-sector vulnerabilities in "smart cities" and beyond. Infrastructure owners and operators, their critical supply chains and their government and NGO partners will need access to a comprehensive, multi-sector mapping and modeling capability. A modeling framework that could provide such capabilities would also need to include the situational awareness and decision support required to enable dynamic, real time response operations addressing complex, Black Sky intra-sector and cross-sector crises.

The Global Infrastructure Network Optimization Model (GINOM™) project and other private and public modeling initiatives, especially those led by leading infrastructure sector organizations, and by DHS, will be essential for assessing these novel and potentially catastrophic sources of fragility, and will provide tools to support response, sustainment and recovery operations.

GINOM

2. Prioritizing Restoration Investments and Plans for Black Sky Scenarios: The United States lacks the criteria and information sharing systems necessary for cross-sector sustainment and restoration operations

Individual sectors and utilities within them typically have their own priorities for sustainment and restoration, optimized for their specific industry and service areas. However, given the extensive infrastructure damage that multi-region Black Sky events will create, the United States needs a nationwide basis to determine which infrastructure services and functions across all sectors are absolutely most vital for: 1) preserving national security; 2) limiting long-term damage to the economy; and 3) preventing infrastructure breakdowns from creating humanitarian catastrophes.

In some cases, such prioritization will only be possible if it is based on planning and associated investment implemented well in advance of a catastrophe, such as by planning for Black Sky hazard-protected, fuel-secure, regionally distributed segments of the nation's black start cranking paths. Without such advance planning and investment, in this electric subsector example, power companies would be unable to significantly "prioritize" restoration operations in real time, since such restoration would, then, be utterly dependent on whichever existing black start cranking paths are available, and the user facilities to which they happen to connect.

DHS has developed a starting point to establish such priorities on a multi-sector basis. In particular, as required by Executive Order 13636, Improving Critical Infrastructure Cybersecurity, DHS has created a "Section 9" list of especially critical infrastructure.[7] But that list focuses on corporate-level priorities and does not provide the granularity needed to guide cross-sector operations in a Black Sky event. Moreover, while DHS informs infrastructure owners whether they are on the list, the Department rarely tells them which – if any – Section 9 assets from other sectors operate in their service territory.

Recommendation: Build a Black Sky Prioritization List (BSPL)

DHS and its industry and government partners should leverage the Section 9 list and many other (usually stove-piped) prioritization initiatives to build a consolidated, "user friendly" list of the most important services and facilities to sustain or restore in Black Sky events. Existing information sharing mechanisms should also be leveraged to ensure that cleared industry personnel are aware of the BSPL assets in their service territories, and can plan for cross-sector sustainment and restoration operations accordingly.

7 Executive Order 13636 – Improving Critical Infrastructure Cybersecurity, February 12, 2013, https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/executive-order-improving-critical-infrastructure-cybersecurity.

3. **Private Sector Coordination:** The private sector is not adequately organized for cross-sector sustainment and restoration operations

Infrastructure owners and operators will need to play a leading role in defending and restoring their own systems in Black Sky events, and in prioritizing and providing cross-sector assistance. Industry leaders have recently taken major steps forward to facilitate such collaborative decision-making. Most important, the coordinating councils of the electric subsector, the financial services sector, and the communications sector have established a Strategic Infrastructure Coordinating Council (SICC) to develop and exercise cross-sector response plans and interface with government leaders.[8]

> Infrastructure owners and operators will need to play a leading role in sustaining and restoring their own systems in Black Sky events.

However, building preparedness for Black Sky events will require the inclusion of a broader range of infrastructure sectors than included in the SICC. Such catastrophic events will also require industry leaders to coordinate sustainment and restoration operations in the face of unprecedented cross-sector failures, including major communications outages.

Recommendation: Build on the SICC to create an expanded, operationally-focused organization for industry collaboration

Infrastructure leaders should leverage the SICC and other emerging coordination mechanisms to create a **Cross-Sector Coordinating Council (CSCC),** which will support broader cross-sector operational planning and coordinate incident response activities. The CSCC will need to account for the widely differing ways in which sectors are organized, and variations in the degree to which they are currently capable of coordinating support operations by their members. But such collaborative decision-making will nevertheless be vital in Black Sky events.

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8 "ESCC Initiatives," Electricity Subsector Coordinating Council, August 2017, http://www.electricitysubsector.org/ESCCInitiatives.pdf.

4. Coordinating Government and NGO Black Sky Infrastructure Support and Population Sustainment: Sustaining and restoring critical services in Black Sky events will require a fundamental repurposing of the U.S. incident response system

The U.S. national incident response system is focused on delivering Federal assistance to states and localities when their own resources prove inadequate. However, in Black Sky events, industry – with new capabilities provided by their own, new coordination capability through a CSCC structure – must lead efforts to sustain and rapidly restore critical infrastructure services to save lives and protect U.S. security. The current system is poorly structured to facilitate industry-led operations.

> The U.S. incident response system is poorly structured to facilitate the industry-led sustainment and restoration operations that will be necessary in Black Sky events.

Filling these gaps by building a new, separate response system only for Black Sky events would be unwise and politically impractical. The National Response Framework and the coordination mechanisms that it supports are so deeply embedded in the United States, and so closely aligned with the Federal system of government and key acts of Congress, that developing and maintaining a "just break glass" system solely for Black Sky events would be extraordinarily difficult.

Recommendations: Put government and NGO support for industry-led, cross-sector infrastructure operations at the heart of emergency management

The 2017 Power Outage Incident Annex provides a critically-needed basis for regional planning against the cascading failures that Black Sky power outages will create. However, in addition to fully engaging infrastructure owners and operators in such planning, emergency managers should also advance a score of other initiatives. Among the most important proposed in this volume:

- **Federal Government Black Sky Support for States and Private Industry:** Reinforce the ability of the Federal Government's National

Response Coordinating Council (NRCC) to prioritize and help guide government support to industry

With FEMA's help, infrastructure owners and operators and Federal officials should pre-arrange to include industry representation of all critical sectors in the NRCC, and ensure that industry decisions made in the proposed CSCC are fully integrated into government response operations.

An especially important aspect of this will be a new effort to address two areas of Black Sky support.

a. **Expanded, Black Sky-Compatible Emergency Power Assets:**

   Since current capabilities are designed to address local hazards, FEMA and the United States Army Corps of Engineers (USACE) should acquire adequate nationally deployed, Black Sky protected emergency generators and related equipment and technical support to address national scale, Black Sky events.

b. **Black Sky Certified Emergency Fuel and Other Supply Chain Resources:**

   Given the urgency of maintaining adequate supply chains for critical resources and services essential to infrastructure restoration and sustainability, FEMA and USACE should work with the CSCC to determine categories of supply chain corporations that should be predesignated as Black Sky certified organizations, and help encourage development of regionally distributed, Black Sky certified capabilities to satisfy this need. As one example, predesignated, Black Sky certified emergency diesel fuel delivery corporations will be essential to ensuring key infrastructure restoration facilities and other critical national facilities will have a continued source for emergency fuel in such disasters. Close coordination with SLTT governments will also be essential as this initiative goes forward.

- **State Government Black Sky Support for Private Industry:** Leverage the unique responsibilities of Governors for disaster response

  Under the U.S. Constitution, governors are responsible for the health and safety of their constituents. At the state level, and with full engagement of local, Tribal and Territorial governments, infrastructure owners and operators should partner with emergency managers to ensure that:

  1. State priorities are taken into account in restoration operations.
  2. Government support for those operations is included in response planning and exercises.

- **Create a new Emergency Support Function (ESF):** ESF-14, Cross-Sector Infrastructure Coordination

  The ESF system is a key coordination structure used by the Federal government for building, sustaining, and delivering response capabilities, including those necessary for sustaining and restoring critical infrastructure. However, ESFs are focused primarily on the delivery of government response capabilities, and are poorly structured to help coordinate industry-government collaboration. By design, ESFs focus on specific response tasks and (in many cases) particular infrastructure sectors.

  Government agencies, NGOs and industry representatives should therefore collaborate to establish a new ESF focused on supporting and addressing the specific challenges posed by cross-sector sustainment and restoration operations in the catastrophes to come.

BLACK SKY EMERGENCY COMMUNICATIONS AND COORDINATION SYSTEM (**BSX**)

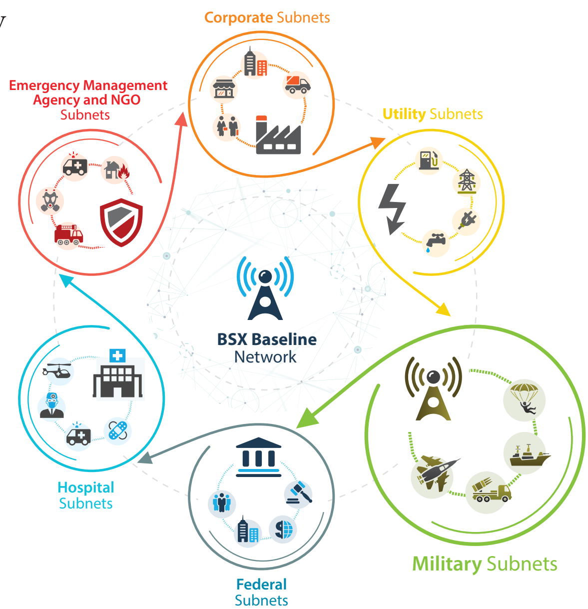
Restructuring the United States' emergency response system to facilitate cross-sector support operations will be useless without survivable, widely distributed, and interoperable systems for processing, communication and coordination.

Many infrastructure owners and operators have emergency communications systems that can help sustain their own functions in a blackout. FEMA, the FBI, state National Guard units, and a handful of other government organizations also have specialized, closely-held systems for dedicated use in manmade or natural disasters.

A widely, multi-sector deployed, interoperable and Black Sky survivable emergency communication and coordination system is a fundamental prerequisite to any restoration and population sustainment operations in national scale catastrophes

However, for multi-sector collaboration, and even for intra-sector emergency restoration operations, the United States will require communication and coordination systems that are widely deployed across all infrastructure sectors and into their critical supply chains, and connected to (and interoperable with) a broad range of private and public sector partners, and an extensive variety of technologies. Those systems will also need the ability to:

- Survive EMP attacks, cyberattacks, catastrophic earthquakes, and other Black Sky hazards.
- Continue functioning in the absence of grid-provided power for a month or more.
- Withstand adversary efforts to disrupt communications or corrupt the integrity of data flows.
- Provide adequate means for critical voice and data connectivity necessary for sustainment and restoration operations across multiple regions of the United States.
- Gather and convey multi-sector situational awareness information essential to decision makers in all sectors, who will find themselves operating in an environment without any of their normal information resources.
- Provide an engine for decision support, keyed to the unique requirements of the local users' equipment, sector by sector, adequate to help manage the scale of a Black Sky complex catastrophe.



An example already exists of a highly survivable and widely distributed system. Since 1998, the U.S. Army has been relying on a survivable, widely-distributed command, control and coordination system – the Blue-Force Tracker – in combat environments.[9]

9 Neil G. Siegel and Azad M. Madni, "The Digital Battlefield: A Behind-the-Scenes Look from a Systems

Based on that proven technology and engineering approach, EIS Council and its partners are developing a Black Sky Emergency Communications and Coordination System (BSX™) to meet the specialized needs of infrastructure sustainment and restoration operations in catastrophic events.

Chapter II of this volume analyzes gaps in current U.S. capabilities for cross-sector communications and coordination. Chapter II also examines how the BSX system is evolving to fill these gaps, describes the prototype system that is already being developed, and identifies next steps for the buildout of the system.

Key findings and recommendations:

1. **Current emergency communications systems cannot provide the multi-sector connectivity and interoperability that will be essential in Black Sky events.**

   Electric companies, water utilities, and other infrastructure owners and operators are making significant progress in acquiring fallback systems that can support their operations in blackouts. However, given the growing interdependencies between these sectors, and the need for close collaboration with NGOs and emergency managers, broad cross-sector connectivity will be vital for Black Sky response operations. No existing system, nor the current collection of disparate systems, can meet that need in a severely disrupted environment.

   BSX design: The BSX is being engineered to provide a common communications system (including hardware and software) to support essential voice and data links between all critical infrastructure owners and operators, and their key government and NGO partners. BSX communications nodes will also be interoperable with any other emergency communications systems that survive the onset of a Black Sky event. In particular, BSX's software will enable it to serve as a "bridge" between previously-incompatible communications systems, thereby expanding the BSX system's reach and capacity.

Perspective," Procedia Computer Science Vol. 28 (2014).

To meet the variable data rate needs for different infrastructures, and during different phases of Black Sky restoration, the system embodies two levels of emergency communication architecture: "BSX™ Basic" utilizes a radio/narrowband network (HF/VHF/UHF) architecture for voice supplemented with limited data services. Easy to establish and operate, technologically stable, it provides a solid, basic capability.

For situations where higher data rates are required, a second "BSX™ Expanded Data Rate" architecture layer utilizes BSX's distributed interoperability resources to host a wider variety of technologies and basing modes. Using a combination of user-selected, fixed site and real-time deployed basing modes, this added architecture layer, while more complex, could support much higher data rates, including local and intercity use of LTE nodes. The system's two-layer architecture is designed for flexibility in meeting user needs and evolving requirements.

2. Long duration power outages will cause failures in many existing communications systems.

Most primary and backup communications systems are supported by emergency power generators. They also have at least limited on-site fuel supplies for those generators, and contracts for fuel resupply. However, blackouts lasting a month or more will put incredible stress on those emergency power capabilities, especially as fuel distribution and supply chains break down.

> Many primary and backup communications systems will not have sufficient emergency power and fuel to survive long duration outages.

BSX design: Each deployed BSX communications node will have sufficient battery and renewable sources of power (including solar and/or wind, where applicable) to sustain operations for a minimum of 30 days.

3. Cross-sector operations will require communications links for vast numbers of users on a common system.

Black Sky operations will require not only multi-sector and industry-government connectivity, but also very large numbers of deployed communications nodes. Analysis by the EIS Council suggests that at least 100,000 to 200,000 interconnected nodes will be required across the United States.

Destroyed satellite dish in Humacao, Puerto Rico (Source: FEMA 11/05/2017)

BSX design: To meet such large scale requirements for system distribution, the BSX system is placing a premium on affordability. The system is also being engineered to be "user-friendly." Rather than requiring emergency personnel to have specific expertise, a packet router equipped with mission-specific software agents at each site determines which radio, frequency and communications links to use for all transmissions. This automation significantly decreases the technical complexity of operating the system.

4. Survivability: relatively few emergency communications systems are hardened to withstand EMP and other Black Sky hazards.

Ensuring that these systems will still be functional after years of infrequent use, and limited maintence, will also be essential.

BSX design: BSX is being specifically designed and engineered to survive Black Sky hazards. The system and its components will be able to withstand an EMP attack and advanced cyber threats, as well as other natural and manmade hazards. BSX is also engineered to be able to lie dormant at unmanned locations for years at a time, requiring only periodic testing, and is capable of quickly transitioning to operational mode when catastrophes strike.

5. Beyond communications and coordination, emergency systems should also provide other essential features to support Black Sky operations.

The BSX provides three such features that will be especially valuable:

- **Situational awareness:** BSX will enable users to remotely acquire diagnostic data from sensors embedded in critical infrastructure systems, thereby providing vastly improved situational awareness in disrupted environments and facilitating targeted, accelerated equipment repair and replacement. Data collected before a disaster strikes will be used to better understand the effects of the event on individual sectors and their cross-sector interdependencies.
- **Data processing:** Infrastructure sustainment and restoration operations in the aftermath of Black Sky events will generate more data than can be assimilated manually. BSX-hosted software will be able to store, sort, process, prioritize, display and forward these data, as well as perform planning and host modeling for situational awareness, task management and decision support for all BSX system users.
- **Decision support:** With that improved situational awareness and data processing, BSX will help users in all sectors make prioritized, optimized, and time sensitive decisions that would otherwise be impossible in the face of cascading, mutually reinforcing failures across highly interdependent infrastructure.

THE WAY FORWARD: BUILDING A SUITE OF BLACK SKY RESPONSE TOOLS AND TECHNOLOGIES

Societal breakdown will loom in Black Sky events unless the technology we use to solve complex problems goes forward in line with the technological advancements that contribute to these challenges. As the organic hyper-connectivity and complexity of our infrastructure networks continue to spiral upward, we must develop the capability to map and model the dynamic operation and behavior of these networks. Infrastructure owners and operators must be able to understand critical interdependencies well enough to protect the system of systems, to make the multitude of real time decisions needed to sustain society during large-scale infrastructure sustainment and restoration operations, and to minimize recovery times following a Black Sky event.

> Given the scale of a Black Sky-caused complex catastrophe, technology to map complex interdependencies and automate sustainment and restoration decision support will be essential to prevent societal collapse.

The emergency communications system described in Section II can contribute to achieving these capabilities. Indeed, it is part of the EIS Council's growing suite of tools being designed and developed for catastrophic event response. The BSX™ Resource Family includes the BSX system itself, the Situational Awareness Network Diagnostic (SAND) System, and the Global Infrastructure Network Optimization Model (GINOM).

- **Black Sky Emergency Communications and Coordination (BSX) System:** The BSX is outlined in the previous section, and detailed extensively in Chapter II. It will provide vital situational awareness and coordination capabilities for all industry sectors and levels of government.
- **Situational Awareness Network Diagnostic (SAND™) System:** SAND is a new initiative for the phased development of remotely monitored, Black Sky compatible diagnostics. It is designed to access both currently available utility and infrastructure data, and to deploy new sensors where required to supplement such data. The data will be used to improve infrastructure modeling and simulation, and provide a foundation for adaptive and optimized decision-making in complex, rapidly changing infrastructure networks. This capability will also be designed to meet an objective of reducing damaging assessment time and effort following a Black Sky event.

  While most modern infrastructure networks include embedded sensors and diagnostic instrumentation, such systems are not always configured to allow for central, remote access to these instruments, and the instruments themselves may have Black Sky survivability concerns. The SAND initiative represents a staged process of adapting such instrumentation, over time, to provide key, Black Sky-survivable situational awareness information, remotely accessed and available, under designated conditions, for importing into GINOM.
- **Global Infrastructure Network Optimization Model (GINOM™):** The GINOM initiative will provide an unprecedented capability for broad, multi-sector situational awareness and decision-making support in Black Sky events. Its mapping function can also guide investments in infrastructure resilience.

- **Complex Adaptive Network Optimization Engine (CANOE™)[10]:** GINOM will run the CANOE software engine, which is an automated system that monitors the current state of a complex, multi-dimensional adaptive network of systems through SAND, and provides continually updated guidance that optimizes recovery efforts based on current, changing "as-is" network states, with the guidance, provided for each system, reflecting the progress and changing status of the full network.

This set of complementary tools and systems will operate together to help the nation respond to Black Sky disasters. BSX, now in the early stages of prototype development, will support voice and data communication, acquire diagnostic data from SAND and other sources, and provide an expandable server network to host GINOM in severely disrupted scenarios. GINOM will provide government and corporate leaders with a decision-support capability, giving them the information they need to understand, prioritize and assure the vital support requirements of lifeline infrastructures.

GINOM will help the infrastructure owners and operators at the heart of restoration operations and their government partners implement the objectives outlined in Chapter II. While prioritization initiatives like the proposed BSPL will be crucial to emergency preparedness, these priorities will need to be fluid, adapting in real time to outages and successful restoration operations. Attempting to manually aggregate and analyze the amount of data required to do so would be impossible.

GINOM will also provide valuable capabilities before Black Sky hazards strike. Its comprehensive modeling tool will be critical to understanding the complex interdependencies of our critical infrastructure systems, allowing industry to optimize infrastructure efficiency and identify resilience gaps. Over time, a comprehensive model of global infrastructure networks can also be used to recommend policies and investments that could shift infrastructure interconnectivity to reduce vulnerable interdependencies.

> GINOM modeling capabilities will also be critical for industry efforts to optimize infrastructure efficiency and identify resilience gaps.

10 Patent pending

These tools will be most effective in Black Sky events if their intended users are able to test and train on their functions in exercises. EIS Council successfully completed the first annual EARTH EX™ exercise in August 2017, providing participants with a multi-sector, international exercise to evaluate and improve restoration support, preparedness, response and recovery plans for severe hazards. EARTH EX is designed to improve resilience to Black Sky outages by allowing participants the opportunity evaluate tools and strategies for catastrophic event response. As the BSX Resource Family continues to develop and improve, future EARTH EX exercises will provide developers and intended users a chance to become familiar with, test and optimize their utility in Black Sky events.