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**DISRUPTIVE EMERGENT SYSTEMS
IN DISASTER RESPONSE**

by

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March 2019

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DISRUPTIVE EMERGENT SYSTEMS IN DISASTER RESPONSE

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ABSTRACT

The 2017 hurricanes in the southern United States provided an impetus for wider social technology use than during previous disaster responses. Hurricane survivors rapidly turned to social media for help, while physically unaffected social media users crowdsourced emergent crisis mapping systems. Volunteers unaffiliated with first responder organizations conducted rescues based on those systems to form new response systems. These new, disruptive emergent systems displaced, supplemented, or filled gaps in the established, federally managed responses. This research examined disruptive emergent systems and associated effects on disaster responses.

A total of thirteen disruptive emergent systems from four hurricane responses were analyzed. This research resulted in a set of eight features and an ontological visualization of disruptive emergent systems. The results show that disruptive emergent systems demonstrated supply responses to survivor demand. That is, these systems emerged through particular capability and organizational mechanism conditions to satisfy survivor demands. Cultural motivations provided the call to action for many of these disruptive emergent systems. These features can be used to understand disruptive emergent systems in the context of future disaster responses.

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LIST OF ACRONYMS AND ABBREVIATIONS

CERT	Community Emergency Response Team
DHS	Department of Homeland Security
EOC	Emergency Operations Center
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
ICS	Incident Command System
JIC	Joint Information Center
JIS	Joint Information System
MAC	Multiagency Coordination
NGO	nongovernmental organization
NIMS	National Incident Management System
NRF	National Response Framework
USCG	United States Coast Guard
USCGA	United States Coast Guard Academy
VOAD	Voluntary Organizations Active in Disaster
WCK	World Central Kitchen

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EXECUTIVE SUMMARY

The 2017 hurricanes in the southern United States provided an impetus for wider social technology use than during previous disaster responses. Hurricane survivors rapidly turned to social media for help, while physically unaffected social media users crowdsourced crisis maps to generate complex and powerful emergent information systems. Volunteers unaffiliated with first-responder organizations conducted rescues based on those systems, converging distinct technologies and individuals to form new response systems. In other cases, new response systems emerged to satisfy other survivor needs, like electricity or food. These new response systems were disruptive to the established response system. That is, these disruptive emergent systems displaced, supplemented, or filled gaps in the established, federally managed responses.

This research sought to reveal the effects of disruptive emergent systems on established disaster response systems. Four major hurricane responses were selected for analysis: Hurricanes Katrina (2005), Sandy (2012), Harvey (2017), and Maria (2017). These hurricanes represent the costliest U.S. hurricanes on record as of mid-2018. Damage due to high winds and flooding were widespread. The scale of the damage and large response areas produced two important effects. The first was that federal response resources were spread thin and dispersed over the affected areas. The second was that the disaster scale, combined with scarce federal resources, provided conditions for need-based emergent solutions. In other words, emergent systems arose based on survivor needs that were not being met in an acceptable timeframe. It is not surprising that emergent systems were developed to provide solutions for the many immediate needs in the aftermath of these each of these hurricanes.

A total of thirteen disruptive emergent systems from the four different hurricane responses were analyzed in this research. A constant comparative grounded theory approach was used to identify properties and features of the disruptive emergent systems. Each system was also analyzed in terms of the National Response Framework's Emergency Support Functions and core capabilities. The analysis showed that disruptive emergent systems are likely to supplement ongoing response activities or fill gaps in Emergency

Support Functions and core capabilities. This research also discovered that these systems emerge based on survivor demand conditions and motivations along with available capabilities and culture.

A total of eight disruptive emergent system features were identified through the grounded theory analysis approach. An ontological diagram was developed from these features to reflect the necessary feature components for a disruptive emergent system within a hurricane response. The diagram, shown in Figure 1, is divided into demand and supply sides with each containing conditions and motivations. Capability and mechanism components form supply conditions while the ability to reduce perceived gaps in response makes up the demand conditions. Cultural components comprise the supply motivations and the ability to respond rapidly to needs falls within demand motivations. This diagram can be used to understand disruptive emergent systems, recognize the conditions and motivations required for these systems to form, and provide a roadmap for the established response system to leverage these systems.

The disruptive emergent systems studied in this research demonstrated supply responses to survivor demand. That is, these systems emerged through particular capability and organizational mechanism conditions to satisfy survivor demands. Cultural motivations provided the call to action for many of these disruptive emergent systems.

Disruptive Emergent System Ontological Diagram

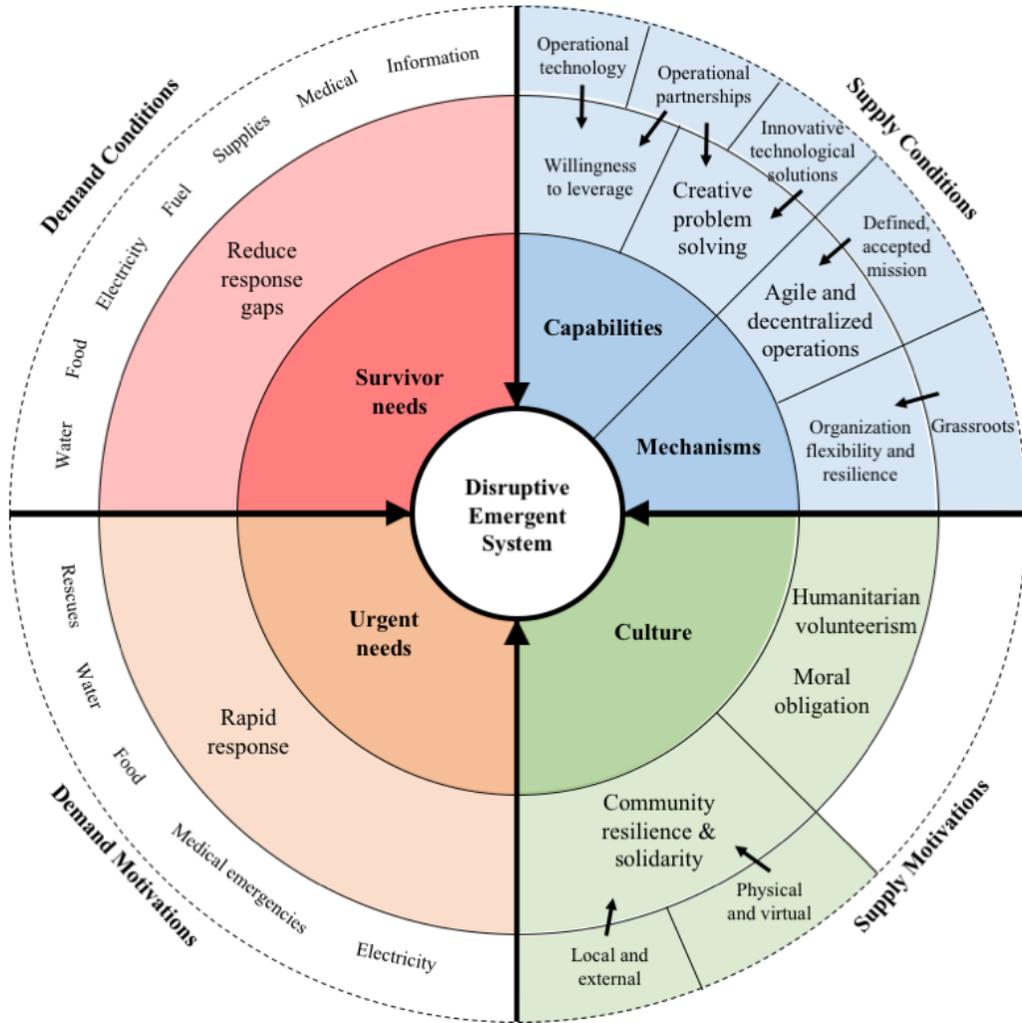


Figure 1. Ontological diagram for disruptive emergent system features.

In addition to these findings, several recommendations can be drawn from the results of this research. First, the established response system should leverage the potential of disruptive emergent systems in future disaster situations by:

- Leveraging existing capabilities: Social media and mobile technologies are readily available to many people and serve as a primary communications platform for some disruptive emergent systems. Social media platforms should be used to pursue integration efforts between systems.

- Leveraging mechanisms: Advanced technologies, like Project Loon or Tesla’s battery packs, were used to fill survivor needs after coordination with government entities. The established response system should leverage fast-track mechanisms to enable public-private relationships that can quickly deploy advanced technology solutions. Coordinate at the lowest level to meet survivor needs in a timely fashion.
- Leveraging culture: Emergent, self-organized groups that provide needed services to survivors should be supported during disaster responses. Before disaster strikes, however, the established response system should adopt an “all-opportunities” approach to promoting community resilience. This approach focuses on people-centric strengths of communities, which may be very location-dependent.

The capabilities, mechanisms, and culture components all reside on the supply side of the disruptive emergent system ontological diagram. Established disaster response systems can also leverage the other side of the diagram to reduce potential demand in terms of conditions and motivations.

- Demand conditions: Investing in resilient electricity generation capacity that does not rely upon a distribution network for fuel or delivery will reduce several immediate needs. Investing in resilient communications networks will provide the ability to disseminate and collect information regarding needs and services. Prestaging supplies with distribution plans in place will also reduce certain demands.
- Demand motivations: Pre-staging water, food, and electricity generation capacity can reduce initial demand for response services.

In general, predictable survivor demands should be proactively reduced before a hurricane strikes. This will reduce the need for disruptive emergent systems from the outset. Second, the established response system should provide support or reduce barriers to disruptive emergent systems that are meeting the highest survivor demands during the

initial response. These systems are valuable force multipliers and should be used. Third, the established response system should support the evolving capabilities and mechanisms of disruptive emergent systems, particularly during the transition to recovery. Finally, the established response system should identify successful disruptive emergent systems and understand the system capabilities and mechanisms throughout the response.

The established systems should learn from these successful systems, so that future response systems need not be disruptive or emergent.

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Also, this is the last degree until we decide it is a good idea again.

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I. INTRODUCTION

A. PROBLEM STATEMENT

The 2017 hurricanes in the southern United States revealed a new reality for disaster response and management. The conditions of the 2017 hurricanes provided an impetus for wider social technology use than during previous disaster responses. Survivors rapidly turned to social media for help while physically unaffected social media users crowdsourced crisis maps, which generated complex and powerful emergent information systems. Volunteers unaffiliated with first responder organizations conducted rescues based on those systems, converging distinct technologies and individuals to form new response systems. Meanwhile, some first responders turned to other information avenues outside of the structured disaster response system. Individuals and groups within first responder organizations created or sponsored technologies to capture social media information to supplement and combine with current information systems and drive better operational decisions.

These emergent, social technology–empowered systems saved many lives.¹ However, despite successfully working alongside first responders with similar goals, the groups using these social technology–driven systems conducted different response actions than organizations operating within the established system.² As a result, these emergent systems inadvertently disrupted the established disaster response system by introducing agile, decentralized methods to the structured, hierarchical disaster response system. Disruptive emergent systems, as defined for this research, are organically developed systems which may supplant a larger, established system or parts of that system. The disruptive emergent systems caught many in the established disaster response system off guard during the 2017 hurricane season. However, disruptive systems have emerged in other hurricane responses as well. While these systems provided overall benefits to the

¹ “Hurricane Harvey Resources,” Summary Hurricane Harvey Response, Humanity Road, last modified September 6, 2017, <https://www.humanityroad.org/situation-reports/usa/hurricane-harvey>.

² For example, Miriam Markowitz, “Hurricane Harvey and Our Vigilante Future of Disaster Relief,” *GQ*, December 7, 2017, <https://www.gq.com/story/cajun-navy-and-the-future-of-vigilante-disaster-relief>.

response, some were not leveraged by the established response system to support a collective response. At worst, some in the established system initially discounted, rejected, or ignored these solutions, reducing the potential positive impact of the emergent systems.³ How could this disruption occur within a structured, hierarchical response framework and why does it matter?

1. Disaster Response Challenges

The disruptive emergent systems in these hurricane responses caused several key challenges for the established disaster response system. For the purposes of this research, the term disaster response system refers to collective response organizations at the federal, state, local, and tribal levels including law enforcement, fire, and emergency medical responders along with federally recognized non-governmental organizations active in disasters. The first challenge for the disaster response system was adapting to individuals reaching out for help via social media platforms. The established disaster response system was organized to use social media platforms to send out information but not to receive assistance requests or unsolicited aid.⁴ Second, the disaster response system contained no mechanism to adapt quickly to those requests while responding within official policy.⁵ Third, the disaster response system was unable to integrate aggregated crowdsourced information rapidly into the response structure for operational use. Finally, unofficial, loosely organized, on-scene volunteer organizations converged with crowdsourced and individual technical solutions to great effect but could not interface well with the disaster response system due to organizational structure incompatibility.⁶

³ For example, see Marcus Gilmer, “During Harvey, Social Media Rose to the Challenge as a Force for Good,” *Mashable*, August 29, 2017, <http://mashable.com/2017/08/29/social-media-harvey-rescues-force-for-good/>; and Lauren Silverman, “Facebook, Twitter Replace 911 Calls For Stranded In Houston,” *NPR*, August 28, 2017, <http://www.npr.org/sections/alltechconsidered/2017/08/28/546831780/texas-police-and-residents-turn-to-social-media-to-communicate-amid-harvey>.

⁴ For an example, see Catherine Shu, “Coast Guard Asks People Stranded by Harvey to Call Them Instead of Posting on Social Media for Help,” *TechCrunch*, August 27, 2017, <https://techcrunch.com/2017/08/27/coast-guard-asks-people-stranded-by-harvey-to-call-instead-of-posting-on-social-media/>.

⁵ For an example, see Silverman, “Facebook, Twitter Replace 911 Calls For Stranded In Houston”; and Marina Koren, “Using Twitter to Save a Newborn From a Flood,” *The Atlantic*, August 28, 2017, <https://www.theatlantic.com/technology/archive/2017/08/harvey-rescue-twitter/538191/>.

⁶ For an example, see Markowitz, “Hurricane Harvey and Our Vigilante Future of Disaster Relief.”

The structure of the U.S. disaster response system is based on the National Incident Management System (NIMS). NIMS is an organizational structure that is mandated to be used by government responders throughout the country to maintain standardization across disparate response organizations.⁷ The convergence of volunteers and technology to form an alternative, decentralized disaster response system does not fall within the NIMS structure, nor does the emergence of alternative information collection and dissemination that disrupts the established system. Despite not fitting into the NIMS structure, these disruptive emergent systems will continue to appear in disaster responses due to the simple fact that conditions for every disaster are different. These conditions may include disaster type, known hazards, geographic factors, population density, infrastructure resilience, or available technology. History has shown that disruptive emergent systems arise in many forms within many different disaster conditions.

2. Relevance and Goal

Understanding the effects of disruptive emergence on disaster response systems is essential for two reasons. First, disruptive emergence through new technology use in disaster areas may increase in the future, reflecting a new reality for disaster response organizations. People in affected areas will seek help by any means available whether those means fall within the established disaster response system or not. Thus, disaster response organizations need to understand the underlying principles of disruptive emergence within disaster responses to make effective decisions regarding organizational flexibility, first responder adaptability, and rapid technology integration. Second, disruptive emergent systems will continue to be developed to benefit victims of disasters, whether originating in the disaster area or not. Rapid organization and deployment of volunteers and resources will continuously be made easier by increasingly advanced and resilient communications technologies. Occupy Sandy's use of mobile technologies, the Cajun Navy's evolution to mobile dispatch strategies, and resilient radio or cellular towers exemplify advanced

⁷ Department of Homeland Security, *National Incident Management System, Third Edition*, October 2017, https://www.fema.gov/media-library-data/1508151197225-ced8c60378c3936adb92c1a3ee6f6564/FINAL_NIMS_2017.pdf, 1–3.

technology and increased infrastructure resilience.⁸ While technology in a disaster situation may be beneficial, however, emergent systems may pose certain public safety concerns. For example, posting addresses of disaster victims in an open forum raises concerns over privacy and security.

This research will focus on two specific goals. The first is to understand the impacts of disruptive emergent systems on contemporary disaster responses. The second is to determine how disruptive emergent systems can improve disaster response systems. Taken together, the objective of these goals is to identify why and how disaster response systems should leverage disruptive emergent systems in future disaster situations.

B. RESEARCH QUESTION

How do disruptive emergent systems affect established disaster response systems?

To answer this overarching research question, the following questions will be examined.

1. What were the effects of disruptive emergent systems on modern disaster responses?
2. What insights do different analysis approaches reveal about the effect of disruptive emergent systems on established disaster response systems?
3. How can insights about disruptive emergence be applied to improve disaster response systems in the future?

C. METHODS SUMMARY

To examine these questions, this research studied four major hurricane responses in the United States since the implementation of NIMS: Hurricanes Katrina (2005), Sandy

⁸ Eric Ambinder et al., *The Resilient Social Network* (Falls Church, VA: Homeland Security Studies and Analysis Institute, 2013), <https://www.hSDL.org/?view&did=751423>, 25–30; Suzanne Ciechalski, “Louisiana’s ‘Cajun Navy’ Rushes to Texas to Help Rescue People from the Floodwaters,” *Mashable*, August 29, 2017, <http://mashable.com/2017/08/29/cajun-navy-houston-harvey-louisiana/>; and Ryan Bell, “After Hurricane Maria, AM Radio Makes a Comeback in Puerto Rico,” *Columbia Journalism Review*, April 23, 2018, https://www.cjr.org/united_states_project/hurricane-maria-puerto-rico-radio.php.

(2012), Harvey (2017), and Maria (2017). Vignettes within each hurricane were identified that described the use or creation of disruptive emergent systems. Each vignette captured characteristics and conditions of the disruptive emergent system and identified the impact on the established NIMS-structured disaster response. The vignettes were analyzed in terms of NIMS-defined response functions within each hurricane to answer the first sub-question: What were the effects of disruptive emergent systems in modern disaster responses?

Each vignette drove iterative identification of disruptive emergence categories, features, and conditions through a grounded theory approach as the primary analysis method. This qualitative, iterative approach resulted in a range of disruptive emergence insights for each hurricane response. The disruptive emergence insights from each hurricane response were collectively analyzed to derive integrated insights. The integration effort distilled the information collected into a concentrated set of observations about the features of disruptive emergence. These observations were compared with an overall analysis of NIMS-defined response functions to answer the second sub-question: What insights do different analysis approaches reveal about the effect of disruptive emergent systems on established disaster response systems?

Finally, the identified disruptive emergent system features were incorporated into an ontological diagram to frame the application of insights to established disaster response systems. This discussion addressed the final sub-question: How can insights about disruptive emergence be applied to improve disaster response systems in the future? The answers to these sub-questions were used to answer the main research question: How do emergent disruptive systems affect established disaster response systems?

D. THESIS SUMMARY

Chapter II provides an overview of the current structure of the U.S. disaster response system outlined in NIMS and other guiding policies. This chapter includes brief reviews of NIMS, the Incident Command System, and the National Response Framework. A discussion of NIMS implementation, roles and responsibilities during hurricane

responses is provided to establish context for disruptive emergence. This chapter concludes with a summary of responses outside of the NIMS structure during hurricane responses.

Chapter III describes the grounded theory approach research design. This chapter establishes the basis for using the constant comparative method to analyze disruptive emergent systems within hurricane responses. This section reviews the methods used to obtain data for the disruptive emergent system vignettes, the analysis methods used for those vignettes, and the procedure used to extract insights from the analysis.

Chapter IV summarizes Hurricane Katrina, the vignettes identified for analysis, and the effect of each disruptive emergent system on the established response system. Each vignette is briefly described with a direct link to the supported, displaced, or filled capabilities of the established disaster response system. Finally, the insights and features resulting from the constant comparative analysis approach are described and analyzed. A review is provided of the characteristics and properties from each vignette and the grounded theory evolution of features and properties. Chapter V follows this same structure for Hurricane Sandy, Chapter VI for Hurricane Harvey, and Chapter VII for Hurricane Maria.

Chapter VIII details the analysis of the collective hurricane responses. In this chapter, the iteration to overall insights is described along with the findings from the aggregated analyses. Following this discussion is a review of the ontological diagram developed through this research. The connections between the diagram, insights, and disruptive emergent system features are detailed in this discussion. The chapter concludes with a discussion of the findings in the context of effects on current systems, insights from the analysis, and potential application of insights to the established disaster response system.

Chapter IX reviews the conclusions of this research and potential future research directions. The insights discovered through this research are applied to present and future disaster response systems. This discussion is framed by the disruptive emergent system features and the ontological diagram. This chapter summarizes the answer to the question: How do disruptive emergent systems affect established disaster response systems?

The overall goal of this research effort was to understand the effects of disruptive emergent systems on disaster responses. This research method was designed to reveal insights into disruptive emergent systems that may help explain how and why the phenomenon occurs and how it may be useful during disaster response.

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II. STRUCTURED DISASTER RESPONSE

To understand how disruptive emergent systems impact the established disaster response system, it is first necessary to understand the established system. There are several key documents that guide U.S. disaster response management. This chapter will briefly review the mandated organizational structures and requirements within these documents, the implementation of those structures and requirements, and highlight the roles and responsibilities described within those structures.

A. DISASTER RESPONSE STRUCTURE IN THE UNITED STATES

The key documents that lay out disaster response roles and responsibilities for federal agencies are the National Incident Management System and the National Response Framework. These documents specify the organizational structure required for federal disaster response. The organizational structure as well as the roles and responsibilities of federal response agencies will be reviewed in this chapter.

1. National Incident Management System

The National Incident Management System (NIMS) is a “comprehensive, nationwide, systematic approach to incident management.”⁹ This approach is scalable from automobile accidents to major national disasters. NIMS is applicable to any incident, standardized for interoperability, and provides the organizational structure for unity of effort.

NIMS was officially adopted in 2004 and is mandated to be used by all federal agencies.¹⁰ State, local, and tribal agencies are not mandated to adopt NIMS but are required to do so to take advantage of Federal Preparedness grants or other funding. This federal implementation strategy, including federal training opportunities for state, local,

⁹ U.S. Department of Homeland Security, *National Incident Management System*, 2.

¹⁰ George W. Bush, Homeland Security Presidential Directive 5, “Management of Domestic Incidents,” The White House (February 28, 2003), <https://www.dhs.gov/sites/default/files/publications/Homeland%20Security%20Presidential%20Directive%205.pdf>.

and tribal agencies, has made the adoption of NIMS widespread through the nation. The Federal Emergency Management Agency (FEMA), the owner of NIMS, manages periodic updates to the doctrine, coordinates with partner agencies on implementation, and manages training courses for federal, state, local, and tribal responders.

NIMS is made up of three components: Resource Management, Command and Coordination, and Communications and Information Management.¹¹ The Resource Management component addresses ongoing preparations for incidents, management during an incident, and special mutual aid agreements. Command and Coordination focuses on operational concepts, including vocabulary and organization structure. This component introduces the Incident Command System, Emergency Operations Centers, Multiagency Coordination Groups, and the Joint Information System. Finally, the Communications and Information Management component lays the framework for communications within an incident, information collection and dissemination, and communication standards.

This chapter will focus on the organizational structure of NIMS required for disaster response from an operational standpoint. Understanding the operational underpinnings of NIMS application and implication of disruptive emergent systems will drive strategic decisions regarding those systems.

2. Command and Coordination within NIMS

The Incident Command System (ICS), described in detail within the NIMS, is a “standardized approach to the command, control, and coordination of on-scene incident management.”¹² ICS provides a standard hierarchy, organization structure, and vocabulary to support agency interoperability and incident command scalability. ICS is the implemented physical and operational structure of NIMS during an incident. ICS specifies the incident command, command staff, and general staff required to manage any type of incident. This structure can grow to meet the demands of large-scale disasters, like hurricanes. Figure 1 is a basic example of the standardized organizational structure.

¹¹ U.S. Department of Homeland Security, *National Incident Management System*, 1–2.

¹² U.S. Department of Homeland Security, *National Incident Management System*, 24.

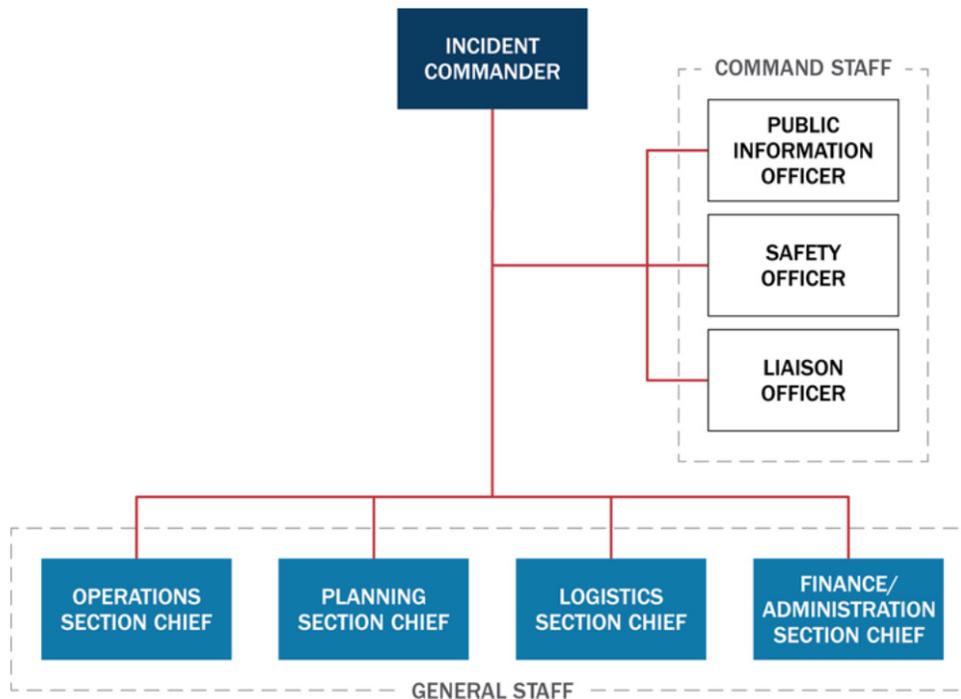


Figure 1. Example of a standard ICS structure. Source: U.S. Department of Homeland Security (2017).

An Emergency Operations Center (EOC) is generally defined as a central location where multiagency staff coordinate to support an incident commander and first responders before and during an incident.¹³ The staff in an EOC have several primary goals: to collect, analyze and disseminate information, to respond to field or incident commander resource requests, synchronize plans, identify current and future resource needs, and provide operational or policy direction as required. The EOC is organized based on the needs of the agency. NIMS provides organization structure examples that reflect the ICS structure, Incident Support Model structure, and agency department structure. State and local EOCs are not required to adhere to these organizational structures.

Multiagency Coordination (MAC) Groups are teams of policy personnel that are part of the remotely located incident management structure.¹⁴ The primary role of MAC

¹³ U.S. Department of Homeland Security, *National Incident Management System*, 35.

¹⁴ U.S. Department of Homeland Security, *National Incident Management System*, 40.

Groups are to support incident commanders by making interagency decisions about policy and resources. MAC Groups, while part of the incident management structure, do not perform any incident command functions. Membership of MAC Groups can vary widely but normally consist of representatives from affected agencies and may include delegates from non-governmental organizations that contribute to the response effort. In some cases, a MAC Group may be comprised of personnel within the EOC.

The Joint Information System (JIS) is designed for the sole purpose of providing “timely, accurate, accessible, and actionable information to the public.”¹⁵ The JIS works with the on-scene Incident Command, the EOC, and off-site MAC Groups to integrate public messaging and ensure consistency across agencies and interagency groups. The JIS is manifested within a Joint Information Center (JIC). The JIC should be near the Incident Commander and the EOC to ease communication logistics. The JIS can implement virtual, satellite, area, or national JICs to support the overall public information mission.

3. National Response Framework

The National Response Framework (NRF) is one part of the National Preparedness System. The NRF is a response guide for all disasters and lays out specific core capabilities required during a national disaster response. The NRF addresses “actions to save lives, protect property and the environment, stabilize communities, and meet basic human needs following an incident.”¹⁶ Executing emergency plans and supporting short-term recovery are also part of response actions.

The NRF identifies 15 core capabilities for incident response. These core capabilities are “activities that generally must be accomplished in incident response regardless of which levels of government are involved.”¹⁷ The NRF also describes the enabling Emergency Support Functions (ESFs) and the primary government agency

¹⁵ U.S. Department of Homeland Security, *National Incident Management System*, 42.

¹⁶ U.S. Department of Homeland Security, *National Response Framework, Third Edition*, June 2016, https://www.fema.gov/media-library-data/1466014682982-9bcf8245ba4c60c120aa915abc74e15d/National_Response_Framework3rd.pdf, 1.

¹⁷ U.S. Department of Homeland Security, *National Response Framework*, 20.

responsible for ESF management. Core capabilities are not the responsibility of a sole response agency or level of government. Each core capability is needed across all response levels and agencies. However, not all core capabilities will be needed for all disaster types. The NRF provides the details for each core capability. The core capabilities for disaster response are:

1. Planning
2. Public Information and Warning
3. Operational Coordination
4. Infrastructure Systems
5. Critical Transportation
6. Environmental Response / Health and Safety
7. Fatality Management Services
8. Fire Management and Suppression
9. Logistics and Supply Chain Management
10. Mass Care Services
11. Mass Search and Rescue Operations
12. On-scene Security, Protection, and Law Enforcement
13. Operational Communications
14. Public Health, Healthcare, and Emergency Medical Services
15. Situational Assessment¹⁸

¹⁸ U.S. Department of Homeland Security, *National Response Framework*, 22–26.

These core capabilities are enabled by one or more ESFs. Each ESF is managed by a primary government agency, known as the ESF Coordinator. Under the direction of the ESF Coordinator, each ESF enables the delivery of select core capabilities. In other words, each ESF provides support for one or more core capabilities. The ESF Coordinators are responsible for management and oversight of the ESF, supported by secondary agencies and non-federal partners. The ESFs for response operations are:

1. Transportation
2. Communications
3. Public Works and Engineering
4. Firefighting
5. Information and Planning
6. Mass Care, Emergency Assistance, Temporary Housing, and Human Services
7. Logistics
8. Public Health and Medical Services
9. Search and Rescue
10. Oil and Hazardous Materials Response
11. Agriculture and Natural Resources
12. Energy
13. Public Safety and Security
14. Superseded by National Disaster Recovery Framework

15. External Affairs¹⁹

These functions provide a consolidated framework to manage the resources and operations necessary to deliver the federal response core capabilities. Table 1 shows the intersection between the core capabilities and each ESF. The NRF specifically designates three core capabilities that are enabled by all ESFs: Planning, Public Information and Warning, and Operational Coordination. With the exception of Fire Management and Suppression, all core capabilities are supported through multiple ESFs. The interconnected nature of core capabilities and ESFs reveals the importance each has within disaster response. The interconnectedness also shows the significance of interagency coordination and support at the federal level to facilitate effective disaster response.

Table 1. Links between Emergency Support Functions and Response Core Capabilities.

Emergency Support Functions	Core Capabilities														
	Planning	Public Information and Warning	Operational Coordination	Infrastructure Systems	Critical Transportation	Environmental Response / Health and Safety	Fatality Management Services	Fire Management and Suppression	Logistics and Supply Chain Management	Mass Care Services	Mass Search and Rescue Operations	On-scene Security, Protection, and Law Enforcement	Operational Communications	Public Health, Healthcare, and Emergency Medical Services	Situational Assessment
1 Transportation	X	X	X		X										
2 Communication	X	X	X	X									X		
3 Public Works and Engineering	X	X	X	X	X	X	X		X	X	X				
4 Firefighting	X	X	X	X				X	X			X	X	X	X
5 Information and Planning	X	X	X												X
6 Mass Care, Emergency Assistance, Temp Housing and Human Services	X	X	X		X		X		X	X				X	
7 Logistics	X	X	X	X	X				X	X			X		
8 Public Health and Medical Services	X	X	X		X	X	X		X	X				X	
9 Search and Rescue	X	X	X								X				
10 Oil and Hazardous Materials Response	X	X	X	X	X	X									
11 Agriculture and Natural Resources	X	X	X		X				X	X					
12 Energy	X	X	X	X					X						X
13 Public Safety and Security	X	X	X									X			
15 External Affairs	X	X	X												

NIMS and the NRF specify organizational structure, mechanisms, and responsibilities for federal government agencies during disaster response.

¹⁹ U.S. Department of Homeland Security, *National Response Framework*, 34–37.

Recommendations within NIMS for state, local, and tribal agencies mirror many federal requirements to set a framework for interoperability between all response levels. NGOs and private sector entities are also encouraged to adopt NIMS in part or whole.

B. NIMS IMPLEMENTATION FOR HURRICANE RESPONSES

The United States has experienced a multitude of man-made and natural disasters since NIMS was implemented. To effectively respond to some of these disasters, states have requested federal assistance or the president has declared an emergency or major disaster under the Stafford Act. The Act provides the mechanism through which funding, resources, and assistance from the federal government may be used to support response operations. Between 2005 and 2018, the president has declared a major disaster 827 times for incidents like floods, hurricanes, tornadoes and fires.²⁰ These major disasters vary in scale and scope. Hurricane disasters are generally quite large and may affect several states or territories with wind damage, flooding, and secondary effects like chemical spills or fires. In a hurricane response, state and local response agencies are often quickly overwhelmed due to capacity constraints.²¹ The NIMS structure is used to organize and manage the large number of response agencies from the federal, state, and local governments that will respond to the hurricane damage. Without the underlying structure of NIMS, federal, state, and local joint responses will be prone to interoperability issues among the various organizations and may risk a less effective response.

In the case of a declaration, FEMA is the lead federal agency for coordinating the response. Within the ICS, state, local, and tribal response agencies will be represented within the functional areas under the unified incident command structure. For a hurricane response, most response needs are immediate which requires a large ICS structure to be in place to direct operations and support. FEMA may stage resources to an area where an

²⁰ “Disaster Declarations by Year | FEMA.Gov,” Disaster Declarations by Year, 2018, Federal Emergency Management Agency, accessed October 17, 2018, <https://www.fema.gov/disasters/year>.

²¹ U.S. Department of Homeland Security, *National Incident Management System*, 60; and U.S. Department of Homeland Security, *National Response Framework*, 50.

emergency declaration is imminent.²² In the case of a major disaster declaration, deployment activities must occur after the disaster occurs.

Even after a federal emergency declaration, state, local, and tribal response agencies will take initial steps to respond to a disaster. Much of the federal organizational structure may be prepositioned for a hurricane response, such as incident command, an EOC, required MAC Groups, and a JIC. However, during or immediately after a hurricane strikes, first responders familiar with the area will be the first on scene, with or without the backing of the ICS organizational structure. Depending upon the circumstances, first responders from all levels may not be able to initially fulfill assigned roles and responsibilities. In these circumstances, other individuals and groups may fill those roles, commonly in an unofficial capacity outside of the NIMS organizational structure.

C. RESPONSE OUTSIDE OF THE NIMS STRUCTURE

The NIMS organizational structure is designed for government response agencies, nongovernmental organizations (NGOs), and private entities.²³ Many of these entities have implemented NIMS with success and are integrated with the ICS. However, NGOs and private entities, including individuals, are not required to implement NIMS or to interface with the federal ICS during a disaster response. NIMS is designed to manage all activities within an incident response, but does not have a mechanism in place to leverage activities that do not fall within, adhere to, or interface with the ICS organizational structure. These activities may supplement or fill coverage gaps in ESFs or core capabilities while falling outside the ICS structure. To begin to understand how these activities occur, several key concepts are defined in the following section.

1. Definitions

Many different types of organizations and systems make up the disaster response ecology. Government response agencies, NGOs, and private entities, such as private companies, all play particular roles in disaster response. NIMS defines NGOs as:

²² U.S. Department of Homeland Security, *National Response Framework*, 31.

²³ U.S. Department of Homeland Security, *National Incident Management System*, 1.

A group that is based on the interests of its members, individuals, or institutions. An NGO is not created by a government, but it may work cooperatively with government. Examples of NGOs include faith-based groups, relief agencies, organizations that support people with access and functional needs, and animal welfare organizations.²⁴

The Red Cross, Habitat for Humanity, and the Humane Society of the United States are readily recognizable NGOs active in disaster response and initial recovery operations. These organizations are well-established groups that perform defined functions within a disaster response, interface with the federal government through NIMS, and fall within the NIMS definition of NGOs. Commonly, these groups are part of the National Voluntary Organizations Active in Disaster (VOAD) forum. These organizations are “officially designated as support elements to national response capabilities.”²⁵ Some NGOs do not interface with NIMS during disaster responses but are known entities prior to the disaster. Furthermore, groups that are formed *during* a disaster response also fall within the NIMS NGO definition. However, these emergent groups have had no interaction with FEMA or federal response agencies prior to the disaster. These groups may operate in parallel to response agencies but perhaps not cooperatively. Parallel or overlapping operations may confuse or frustrate survivors in an already chaotic disaster environment.

In addition, emergent groups may not be aware of NIMS or the ICS. These groups rapidly develop and evolve emergent response systems as solutions independent of the established NIMS-based structure and plans. Established NGOs and first responder organizations can also create these types of emergent systems. In fact, first responder organizations have been known to develop emergent systems to accommodate situational needs. For the purposes of this research, the term emergent system is defined as:

Emergent system: A system generated in an organic manner, usually rapidly, to solve a problem that the current system does not.

System solutions developed within a disaster response environment are generally created to supplement or fill perceived coverage gaps in established response operations.

²⁴ U.S. Department of Homeland Security, *National Incident Management System*, 68.

²⁵ U.S. Department of Homeland Security, *National Response Framework*, 9–10.

These solutions can conceivably displace established response capabilities, allowing the established response operations to concentrate elsewhere. Solutions with supplemental, gap filling, or displacement characteristics can be defined as disruptive systems due to the inherent replacement component within each of these characteristics.²⁶ Christensen et al. describe disruptive innovations as products or services that may not have the same features as an established product or service.²⁷ However, these products or services are “typically simpler, more convenient, and less expensive” than the established versions.²⁸ A system that is good enough may be just as desirable for disaster survivors as the established disaster response system. Disruption, in this case, should be considered in terms of shifting away from the current status quo in favor of a new service, service provider, or strategy that can satisfy the same needs. NGOs, emergent groups, or even components within the established response system are able to create and sustain disruptive systems. For the purposes of this research, the term disruptive system is defined as:

Disruptive system: A system that supplements, displaces, or fills coverage gaps of currently accepted systems or solutions.

The NIMS organizational structure for disaster response is able to accommodate and even leverage some emergent systems. The NIMS organizational structure can also accommodate disruptive systems and may leverage these systems by creating public-private partnerships. For example, during the Hurricane Sandy response, the National Guard and American Red Cross provided supplies to Occupy Sandy for distribution.²⁹ The National Guard and the American Red Cross, operating as part of the established response,

²⁶ Duplicative efforts are not included in this definition. Supplemental, gap filling, or displacement actions are essentially all duplicative to the established response system. Double coverage in a particular area of response may be viewed as duplicative only if the same action is completed twice. However, many actions within a disaster response are not conducive to duplication. For example, multiple assets can be deployed for a single rescue case, but the survivor is usually rescued from a particular location once.

²⁷ Clayton M. Christensen, et al., “Disruptive Innovation for Social Change,” *Harvard Business Review*, December 2006, <https://hbr.org/2006/12/disruptive-innovation-for-social-change>.

²⁸ Christensen et al., “Disruptive Innovation for Social Change.”

²⁹ Larissa MacFarquhar, “Occupy Sandy,” *The New Yorker*, November 3, 2012, <https://www.newyorker.com/news/news-desk/occupy-sandy>; and Allison Kilkenny, “Occupy Sandy Efforts Highlight Need for Solidarity, Not Charity,” *The Nation*, November 5, 2012, <https://www.thenation.com/article/occupy-sandy-efforts-highlight-need-solidarity-not-charity/>.

recognized that Occupy Sandy was filling a gap in response coverage and could distribute supplies more effectively. While these solution types can be individually accommodated by the NIMS structure, integrating systems that are both emergent and disruptive may be challenging. For the purposes of this research, the term disruptive emergent system is defined as:

Disruptive emergent system: An organically developed system or solution that supplements, displaces or fills certain aspects of an established system or solution.

Disruptive emergent systems evolve over time and are emergent only in the initial solution development stages. As the system matures during the response, it becomes less emergent while taking root in the response environment. The disruptive characteristic of the system will persist until the system is integrated into the federal response organization. This integration point occurs when emergency planners can account for the system within the NIMS organizational structure to support a core capability or ESF. Alternatively, the system may never integrate into the federal response system. In this case, the disruptive system, even if performing parallel functions to the federal system, will continue to supplement, displace, or fill federal roles and services.

2. Volunteers and Emergent Organizations

During disaster responses, citizens commonly serve as the initial wave of first responders.³⁰ Additionally, volunteers are usually necessary throughout the response to fill response gaps left by government capacity shortfalls.³¹ Volunteers may be part of a recognized response organization before the disaster or may sign on during the response. Others may volunteer as individuals on their own volition. While the NRF includes a volunteer management annex to leverage volunteer organization support, individuals previously unaffiliated with a volunteer organization are not obligated to volunteer services through an established organization. Many volunteers will serve through established

³⁰ U.S. Department of Homeland Security, *National Response Framework*, 26; and Lauren S. Fernandez, Joseph A. Barbera, and Johan R. van Dorp, "Strategies for Managing Volunteers during Incident Response: A Systems Approach," *Homeland Security Affairs* 2, no. 3 (October 2006), <http://hdl.handle.net/10945/25078>.

³¹ U.S. Department of Homeland Security, *National Response Framework*, 12.

NGOs, such as the American Red Cross, or as members of their local Community Emergency Response Team (CERT).³² CERTs and established NGO volunteers have procedures available to integrate with the federal disaster response organization. Spontaneous volunteers who are unaffiliated with a response organization may or may not interface with the disaster response system.

Unaffiliated volunteers have self-organized into unofficial, CERT-like groups to perform many different functions during a disaster response. This self-organization can create emergent solutions for affected communities that disrupt (supplement or fill gaps in) the federal response. Advances in communications technologies have made self-organizing easier than in previous responses. Individuals in the field may coordinate in real time with each other and with virtual volunteers. This capability lowers the barriers to entry for potential volunteers, particularly when traveling to the disaster area is not an option. Examples of these capabilities and effects will be explored in subsequent chapters.

3. Integrated Response

The NRF states that “Government resources alone cannot meet all the needs of those affected by major disasters. All elements of the community must be activated, engaged, and integrated to respond to a major or catastrophic incident.”³³ Integration is defined within the NRF as “the ability for the response coordinating structures to link to and share information,” which includes coordinating operations or strategies for “effective emergency response.”³⁴ Integrating community elements, including disruptive emergent organizations, into the federal response is contingent on integration plans and requirements. NIMS requires a liaison officer for an incident or unified command during a disaster response.³⁵ The liaison officer is responsible for coordinating with agencies, NGOs and other groups not included within the incident command structure. Known organizations

³² E.g. “Community Emergency Response Team | Ready.Gov,” Community Emergency Response Team, U.S. Department of Homeland Security, accessed November 7, 2018, <https://www.ready.gov/community-emergency-response-team>.

³³ U.S. Department of Homeland Security, *National Response Framework*, 4.

³⁴ U.S. Department of Homeland Security, *National Response Framework*, 45.

³⁵ U.S. Department of Homeland Security, *National Incident Management System*, 27.

have clearly defined missions, procedures, roles, responsibilities and demonstrated capabilities. Disruptive emergent organizations may not initially possess any of these characteristics. In this case, the liaison officer may not have enough information to begin the integration process, particularly if the liaison officer does not know the organization exists. Additionally, a disruptive emergent organization may not understand NIMS, may not know to reach out to the liaison officer, or may not want to integrate with the federal response. On top of this mutual lack of knowledge, both parties are primarily concerned about executing the response mission and may not have time to understand the integration process. Even if the liaison officer knows about the disruptive emergent organization, she may be hesitant to integrate with an unknown organization.³⁶

On the other hand, NGOs that are part of the ICS may also create disruptive emergent system solutions for certain mission-centric problems. These solutions are developed for the same reasons that all disruptive systems are created within a disaster: to supplement or fill perceived gaps in the federally managed response. These systems are also emergent due to the organic source of the solution.

The integration challenges that liaison officers and the NIMS organizational structure face with disruptive emergent systems, including organizations and mission solutions, stem from the nature of these systems. Disruptive emergent systems may supplement or fill perceived mission gaps. These characteristics mean that emergency planners may not be able to account for them beforehand as part of a response plan. A question therefore arises: how can the NIMS organizational structure identify and leverage the advantages provided by disruptive emergent systems within disaster response?

³⁶ Ambinder et al., “The Resilient Social Network,” 24, 69.

III. RESEARCH DESIGN

A. GROUNDED THEORY APPROACH

A careful review of current explanatory theories revealed no satisfactory model to understand disruptive emergence within disaster response. Disruptive innovation theory, the most recognizable theory regarding disruption, showed initial promise for disaster response applications. However, researchers have raised concerns that the central theoretical ideas to disruptive innovation have not been subjected to recent rigorous academic review like other theories.³⁷ Christensen, who originally theorized about disruptive innovation, surmised that the theory cannot be applied outside business studies without significant modification.³⁸ Another promising idea, catalytic innovation theory, which is a derivative of disruptive innovation theory, also requires substantial alteration to be applied in studies beyond social change business innovations.³⁹ Neither theory readily applies to disaster response missions like search and rescue, since both are centered on concepts like maximizing market share or profit. Sending the maximum number of search and rescue teams to rescue survivors in the shortest amount of time is analogous to saturating a short-lived market with many competitors. Modifying existing business theories to understand disaster response systems may reveal novel insights, but may potentially leave important insights undiscovered.

Lack of an applicable theory or model therefore leads to an inductive and grounded approach. In a grounded theory approach, insights can be developed through incident analysis without a preconceived theoretical framework. While this approach may not lead to a generalizable theory, it is a discovery method that can produce insights grounded within the disaster response domain. Insights generated using this approach can be used as

³⁷ Michael R. Weeks, “Is Disruption Theory Wearing New Clothes or Just Naked? Analyzing Recent Critiques of Disruptive Innovation Theory,” *Innovation: Management, Policy & Practice* 17, no. 4 (2015): 417–28, <https://doi.org/10.1080/14479338.2015.1061896>.

³⁸ Clayton M. Christensen, Michael E. Raynor, and Rory McDonald, “What Is Disruptive Innovation?” *Harvard Business Review*, December 2015, 44–53.

³⁹ Christensen et al., “Disruptive Innovation for Social Change.”

the basis of a domain specific theory or framework. The constant comparative method within the grounded theory approach was used to develop insights in this research.⁴⁰

Glaser and Strauss outline the constant comparative method's four stages.⁴¹ These are: "(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory."⁴² Glaser and Strauss point out that after beginning the process, the stages are continuous and may be concurrent with other stages "until the analysis is terminated." Incidents are compared until new property and category information is exhausted or no more data exists. According to Glaser and Strauss, all stages of the process will have been conducted and iterated when this point of analysis has been reached. The properties and categories revealed from this constant comparative process will have been reduced and scoped to a new theory or set of insights.

The primary objective of this research is to understand how emergent disruptive systems affect established disaster response systems. The insights developed to achieve this objective, using the constant comparative method, were based on disruptive emergent systems within hurricane responses. These systems and their use were analyzed as incidents within hurricane responses and are referred to as vignettes in this research. Multiple vignettes were examined within each hurricane response. The vignettes are episodic and generally occur concurrently within each hurricane response.

B. SCOPE

Responses to Hurricanes Katrina (2005), Sandy (2012), Harvey (2017), and Maria (2017) were selected for review for several reasons. First, the selected hurricanes represent the costliest in U.S. history with large response mechanisms. Second, the 12-year timeframe of hurricane responses span the implementation of NIMS and rapid technological advancements. Third, Hurricanes Harvey and Maria, while occurring in the

⁴⁰ Barney G. Glaser and Anselm L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research* (New Brunswick: AldineTransaction, 1967), 105.

⁴¹ Glaser and Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*, 105.

⁴² Glaser and Strauss, 105.

same year, exhibited very different outcomes in terms of technology and responses. Finally, all four hurricane responses presented forms of emergent systems.

This research was limited to the effects disruptive emergent systems had on an established disaster response system. This research is not a critique of past disaster response actions, nor is it a comprehensive review of actions taken during responses. This research focused solely on disruptive emergent systems within each hurricane response to the extent that information was available. To that end, this research did not study the legal, privacy, or safety concerns related to disruptive emergent systems except as necessary to understand the system's impact on the disaster response. The examination of each hurricane reviewed only the response phase of each and considered emergent solutions only in the response and transition to recovery.

C. VIGNETTE IDENTIFICATION AND DATA SOURCES

The vignette identification process focused on instances of disruptive emergent systems within the context of each hurricane response. Disruptive emergence vignettes were identified based on the conceptual definition. Disruptive emergent systems are defined for this research as *organically developed systems that supplement, displace or fill certain aspects of the established system*.

Organic actions or narratives within each hurricane response were flagged as *emergent solutions*. Organic indicates systems that arise and grow outside the structure of the established disaster response system. The emergent solutions were examined against core capabilities and responsibilities of the established response system as defined in the National Response Framework.⁴³ Any evidence of supplemented, displaced, or filled capabilities within the response system was an indication of a disruptive system.

- Supplemental actions reflect similar missions accomplished in parallel.
- Displacement actions reflect situations in which the disruptive system replaced existing response efforts.

⁴³ U.S. Department of Homeland Security, *National Response Framework*, 20–27, 33–38.

- Filled capabilities indicated that actions were expected by the established system but were completed by the disruptive system.

Each vignette exhibited some form of organic development and supplemented, displaced, or filled capability gaps.

The identified vignette data described the use or creation of disruptive emergent systems, discussed the characteristics and conditions of each, and identified the impact on the established NIMS-structured disaster response. Information from each vignette drove the iterative identification of disruptive emergence categories, features, properties, and conditions. A total of 13 vignettes were identified across the four hurricane responses.

The data for the vignettes were extracted from eight primary sources, including two major after-action reports, three videos, one press release, one book of first-hand interviews, and one Twitter feed. Secondary sources included 40 news reports and three organizational websites. Many other sources were referenced as background for each hurricane response. The vignette data were limited within each hurricane response by several factors. First, the prevalent topic for Hurricane Katrina publications was the government response with a particular focus on failures. In fact, two prominent government reports do not mention the disruptive emergent systems identified and analyzed in this research.⁴⁴ Second, sources from recent hurricane responses are concentrated in news reports, videos, and social media. This recency effect, in combination with a higher degree of information availability, shifted the nature of sources and provided less distilled accounts of disruptive emergence. Finally, several identified disruptive emergent systems were not extensively covered through media sources or recognized in government reports which limited the number of unique references available for those systems.

⁴⁴ Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina, *A Failure of Initiative: Final Report of the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina* (109th Congress, February 15, 2006), [https://www.gpo.gov/fdsys/search/pagedetails.action?browsePath=109/HRPT/\[300;399\]&granuleId=CRPT-109hrpt377&packageId=CRPT-109hrpt377&fromBrowse=true](https://www.gpo.gov/fdsys/search/pagedetails.action?browsePath=109/HRPT/[300;399]&granuleId=CRPT-109hrpt377&packageId=CRPT-109hrpt377&fromBrowse=true); and Frances Fragos Townsend, “The Federal Response to Hurricane Katrina: Lesson Learned” (The White House, February 2006), <http://www.au.af.mil/au/awc/awcgate/whitehouse/katrina/katrina-lessons-learned.pdf>.

D. DISRUPTIVE EMERGENT SYSTEM VIGNETTE ANALYSIS

Contextual factors for each vignette were noted, such as environment, infrastructure, technology, or information availability, to understand the response conditions for each disruptive emergent system studied. Each piece of information captured within a vignette was coded to support the constant comparative method of analysis. Each coded data point was compared to previous data points to identify categories or properties within the vignette.

The vignettes were coded by key terms that represented concepts, ideas, actions, tools or other artefacts within the vignette. Each vignette source was coded independently; that is, new codes were generated frequently rather than reframing or force-fitting existing codes. The list of codes for all vignettes within each hurricane is in the Appendix. Codes that represented similar concepts between sources were grouped into larger scoped codes within the vignette in the spirit of the constant comparative method. A code was used only once per source, normalizing a potential code weight issue between sources. This ensured equal weight for all codes within and between sources.

Next, the coded data from each vignette was compared to previously coded vignettes. Emergent properties and features revealed through this integration activity modified some categories. The modified categories were used for additional vignette codes. This process was continually iterated until all vignettes within the hurricane response were analyzed and compared. The objective of this activity was to continue the constant comparison to reveal emergent properties or features across the analyzed vignettes within each hurricane response. Each hurricane was analyzed independently to capture unique codes, properties, and features to be compared across the four hurricane responses.

The emergent properties and associated features were then integrated across hurricane responses. The integrated properties and features were reduced into concentrated insights of disruptive emergence within disaster response systems. This reduction activity involved combining, abstracting, and culling categories to create overarching insights.

This qualitative, iterative approach resulted in a range of disruptive emergence insights for each hurricane response. The integration effort distilled the categories and

properties into concentrated insights of observed disruptive emergence. This integration resulted in a foundation for a disruptive emergent system ontology for disaster response. This ontology foundation may be used to understand the effects of disruptive emergent systems on disaster response systems and serve as a springboard for future research in this area. The disruptive emergent system insights were then used to answer the main research question: How do emergent disruptive systems affect established disaster response systems?

E. LIMITATIONS

Several limitations for this research exist. First, this research was limited to data available through open sources. This limitation was put in place to attempt to understand disruptive emergent systems through an open lens. By pursuing this course of data collection, the data can support a repeatable methodology. Primary sources were used when available, with the exception of interviews. The limitation was also emplaced to reduce potential recency effects from available data given the time span between Hurricanes Katrina and Maria. Reports and analyses were being published about Hurricanes Harvey and Maria at the same time this thesis was published. The second limitation was the use of a qualitative methodology, specifically the grounded theory approach. This methodology is beneficial for discovering insights and patterns but is not designed for hypothesis testing.

F. ANALYSIS STRUCTURE

Hurricanes Katrina, Sandy, Harvey, and Maria represent the costliest U.S. hurricanes on record as of mid-2018. Damage due to high winds and flooding were widespread. The scale of the damage and large response areas produced two important effects. The first was that federal response resources were spread thin and dispersed over the affected areas. The second was that the disaster scale, combined with scarce federal resources, provided conditions for need-based emergent solutions. In other words, emergent solutions arose based on survivor needs that were not being met in an acceptable timeframe. Emergent solutions were inevitable in each of these hurricane responses considering the fact that many needs were immediate in the aftermath of these storms.

Each of these hurricane responses were examined for disruptive emergence. The following chapters introduce each hurricane and vignettes of several disruptive emergent systems discovered through this research. Each vignette description reviews the disruptive emergent system and the elements of the established disaster response system that were supplemented, displaced, or filled by the solution. The effect of the disruptive emergent solution on the established disaster response system follows each description. After the vignette descriptions, the constant comparative analysis approach results are reviewed, followed by an analysis of the resultant properties and features. The properties and features are then analyzed within the context of the hurricane response.

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IV. HURRICANE KATRINA

Hurricane Katrina struck the Gulf Coast of Louisiana and Mississippi on August 29, 2005 as a Category 3 storm. The storm surge from the hurricane caused the New Orleans levee system to fail which resulted in widespread flooding throughout roughly 80 percent of the city.⁴⁵ The area experienced extensive power and communication outages. The city's pumping systems failed due to power outages and flooded equipment. Thirty-eight 9-1-1 call centers were disabled and fifty area radio stations ceased broadcasting. Approximately 770,000 people in the overall affected area were displaced. State and local response agencies were largely incapacitated by damaged facilities, flooding, and communication outages.⁴⁶ In the immediate aftermath of Hurricane Katrina, many victims were left with few options to fulfill basic needs or for rescue. These immediate gaps persisted for several days. To fill these gaps, several emergent solutions arose to supplement the disaster response efforts. These solutions include the semi-organized efforts of what came to be known as the Cajun Navy, the Soul Patrol, and the decentralized efforts of the NOLA Homeboys. Other gaps in services were filled by emergent and self-organized community-centered clinics. The Common Ground Relief Collective was organized to fill some medical needs along with other basic necessities during the disaster response phase.

A. CAJUN NAVY, THE NOLA HOMEBOYS, AND THE SOUL PATROL

The post-disaster named Cajun Navy was a group of volunteers with boats capable of navigating the shallow water filling the streets of New Orleans and Baton Rouge. Whether on their own accord or in response to televised and radio broadcasts for help, approximately 350 to 400 people with boats formed a loosely organized urban flood rescue

⁴⁵ Townsend, "The Federal Response to Hurricane Katrina: Lesson Learned," 6.

⁴⁶ Townsend, "The Federal Response to Hurricane Katrina: Lesson Learned," 37.

operation.⁴⁷ These volunteers piloted through city streets to lift people from the water and down from rooftops, sometimes under the threat of jail. In some cases, law enforcement officials ordered would-be rescuers to turn back or be arrested.⁴⁸ Many of these individuals turned around, though others found alternative boat launch points. The volunteers that made up the Cajun Navy are credited with saving approximately 10,000 people from those dire circumstances.⁴⁹ At the same time, residents within New Orleans who had access to boats began to conduct the same type of rescues. Historian Douglas Brinkley called one group of these residents the NOLA Homeboys.⁵⁰ Another was the self-named Soul Patrol with a fleet of five boats.⁵¹ Some of these residents loosely organized into neighborhood relief groups, providing basic supplies and food to those in need.⁵²

The Cajun Navy, the NOLA Homeboys, and the Soul Patrol did not operate within the NIMS organizational structure and, at times, completed rescues in defiance of law enforcement orders to stay clear of certain areas. These volunteers rescued fellow citizens in dangerous floodwaters and in areas with reported shootings and looters with no support from federal, state, or local authorities. Had these volunteers experienced any trouble with their boat, they would have become rescue cases themselves, hence the law enforcement orders. However, the volume of victims needing rescue was too high for government responders. The rescues that the Cajun Navy, NOLA Homeboys, and Soul Patrol conducted supplemented the federal government's Emergency Support Functions (ESF) #6 Mass Care, Emergency Assistance, Temporary Housing, and Human Services and #9 Search and

⁴⁷ "How Citizens Turned into Saviors after Katrina Struck," *CBS News*, August 29, 2015, <https://www.cbsnews.com/news/remembering-the-cajun-navy-10-years-after-hurricane-katrina/>; Billy Gunn, "Greatest Story Never Told: Acadiana Boaters Braved Danger, Arrest to Rescue New Orleans-Area Residents Trapped by Hurricane Katrina Floods," *The Advocate*, September 3, 2015, https://www.theadvocate.com/acadiana/news/article_97dc876a-c30c-5e31-85ca-db001a004962.html; and Herman Fuselier, "Cajun Navy Haunted, Inspired by Katrina Memories," *The Advertiser*, August 28, 2015, <https://www.theadvertiser.com/story/news/local/louisiana/2015/08/31/cajun-navy-haunted-inspired-katrina-memories/71283996/>.

⁴⁸ Gunn, "Greatest Story Never Told."

⁴⁹ "How Citizens Turned into Saviors after Katrina Struck."

⁵⁰ Douglas Brinkley, *The Great Deluge: Hurricane Katrina, New Orleans, and the Mississippi Gulf Coast* (New York: HarperCollins, 2006), 303.

⁵¹ Brinkley, 308.

⁵² Brinkley, 303.

Rescue. By conducting these operations and supporting these ESFs, these volunteers served as force multipliers to the federal government with core capabilities #9 Mass Care Services and #10 Mass Search and Rescue Operations.

The supplementary actions of the Cajun Navy, the NOLA Homeboys, and the Soul Patrol conducted for the response effort provided much needed aid to hurricane and flood victims. The successes enjoyed by these groups shored up a general distrust for the federal system in the region. Dyan “Mama D” French Cole was one of the impromptu leaders of the post-named NOLA Homeboys in the Seventh Ward. Her distrust in the federal response system was made clear during her testimony before Congress in December of 2005. She said, “You know what we need right now? We need ya’ll to take FEMA and the Red Cross ... just get ‘em outta my neighborhood.”⁵³

B. COMMON GROUND RELIEF COLLECTIVE AND COMMUNITY CLINICS

Some people refused to evacuate New Orleans, did not hear the late evacuation orders, or were unable to do so due to circumstance. Roughly 60,000 people remained within the city and needed to be rescued or supported in some way. For some in New Orleans, the slow response from the federal government was considered a life or death situation. People in the Algiers neighborhood experienced no flooding but were challenged by no power, running water or public services. These challenges included medical care. Four days after the hurricane struck, four young men on bicycles rode around the neighborhood, asking people if they needed medical attention.⁵⁴ These “street medics” provided basic medical care to the neighborhood and inspired the solidarity-centric Common Ground Relief Collective, an emergent neighborhood organization focused on providing basic community resilience services. These services included basic medical care and supplies distribution during the initial response phase after Hurricane Katrina.⁵⁵

⁵³ Brinkley, 309.

⁵⁴ Tim Shorrock, “Common Ground,” *Mother Jones*, March/April 2006, <https://www.motherjones.com/politics/2006/03/common-ground/>.

⁵⁵ Shorrock.

These volunteers were not part of any organized government response and, like the Cajun Navy and the NOLA Homeboys, did not operate through the NIMS structure. The initial “street medics” that inspired the Common Ground movement were not authorized to be there, much less provide any type of medical care. However, the clinic that sprang up in the wake of these actions eventually gained legitimacy by receiving clinic supplies distributed by the National Guard while continuing to operate outside the established government system.⁵⁶ The coverage gap left by federal, state, local and non-governmental agencies in the Algiers neighborhood provided the impetus for the Common Ground Relief Collective and its emergent services. The group’s public health and medical surge services filled the federal government’s ESF #8 Public Health and Medical Services. By filling this function, Common Ground Relief Collective and other clinics supported the federal core capabilities #9 Mass Care Services and #14 Public Health, Healthcare, and Emergency Services.

The gap left by the established disaster response system allowed the Common Ground Relief Collective and other clinics to provide needed services.⁵⁷ These groups left a positive impression on neighborhoods in New Orleans that persist today in the form of a permanent Common Ground Health Clinic in Algiers.⁵⁸ However, like the Cajun Navy and NOLA Homeboys, the success of the clinics served to displace trust in the established response system, despite the support eventually received from parts of the established system.⁵⁹

These disruptive emergent systems affected the established response system in two distinct ways. The first is that these systems supported the overall response system by filling response gaps. Response coverage did not exist in areas like the Algiers

⁵⁶ Shorrock.

⁵⁷ Jacquie Bauer, *Heart to Heart International Kansas Team One of First to Respond* (Marrero, LA: Jefferson Parish Department of Public Information, 2005), <https://www.hearttoheart.org/wp-content/uploads/2015/08/10sept05-Heart-to-Heart-International.pdf>; “Anarchists Providing Medical Aid in New Orleans,” hosted by Noah Adams, *Day to Day*, on NPR, September 23, 2005, <https://www.npr.org/templates/story/story.php?storyId=4860770>; and Shorrock, “Common Ground.”

⁵⁸ “Common Ground Health Clinic - Home,” Common Ground Health Clinic, last modified 2017, <http://www.cghc.org/index.html>.

⁵⁹ Shorrock.

neighborhood and the Seventh Ward. These disruptive emergent systems rose up to address the needs of survivors. The second is a general trend shifting trust away from the established response system. This shift is related to the successes of these disruptive emergent systems and the accompanying perceived failure of the established system to respond.

C. INSIGHTS AND ANALYSIS

The aggregated analysis of the Cajun Navy, NOLA Homeboys, community clinics, and Common Ground Relief vignettes resulted in 51 specific codes. The codes for Hurricane Katrina are listed in the Appendix. The coded vignette data were categorized and condensed into properties and features within each vignette that were carried over to the next coding analysis. Through this process, five properties and features of these disruptive emergent systems were revealed within the Hurricane Katrina response in New Orleans. The properties and features evolution from the first vignette analysis to the final analysis is shown in Table 2.

Table 2. Evolution of disruptive emergence properties and features through the Hurricane Katrina analysis.

Initial Vignette Features	Final Vignette Features
Time to respond	Response time drove decision making
Unmet needs / basic necessities	Unmet survivor needs / basic necessities
Accepted methods and procedures	Insufficiency of accepted methods and procedures
Agile, decentralized services	Agile, decentralized services
	Community resilience attitude - solidarity

The initial coding from the first vignette revealed four conditions and features of disruptive emergent systems within this hurricane response. These features are divided between the established response system and the analyzed disruptive emergent systems.

- *Time to respond* addressed response time of both the established disaster response system and the disruptive emergent system.

- *Unmet needs and basic necessities* were conditions of the response environment. That is, survivors' needs were not met in an acceptable timeframe or at all, linking these conditions with the previous feature. In many cases, this meant that the established system did not provide services or necessities in certain areas.
- *Accepted methods and procedures* captured the codes that referenced established response system processes, the failures of those processes, and alternative processes developed through the disruptive emergent system.
- *Agile and decentralized services* was a clear feature of the disruptive emergent systems that was different from the established disaster response system.

Coding the second vignette built upon the previous analysis. This final coding resulted in five conditions and features of disruptive emergent systems.

- The *response time drove decision making* feature was prevalent across the vignettes. The established system's response was perceived to be not acceptable in some cases which drove individuals to collaboratively make decisions and take actions. The ability of survivors and volunteers to rapidly respond to unmet needs also drove their decision making.
- The link between the second feature, *unmet survivor needs and basic necessities*, and the first strengthened through the final iteration of coding. Unmet survivor needs included perceived unacceptable response times along with the absence of disaster support necessities.
- Unmet needs connected to the third feature, *insufficiency of accepted methods and procedures*. This feature is a condition of the established system's operations within the response environment. The insufficiency creates gaps in the response effort that allows disruptive emergent systems to grow and fill the space.

- A common feature among the disruptive emergent systems was the ability to provide *agile, decentralized services* to survivors. These services were rapidly adjusted as needs and circumstances changed.
- Finally, survivors demonstrated a distinct attitude toward *community resilience* that emphasized *solidarity*. Survivors that created or participated in a disruptive emergent system were driven by a strong community connection and desire to help fellow survivors.

Taken together, the disruptive emergent systems within the Hurricane Katrina response required two specific types of disaster environment conditions. The first is at least one gap or shortcoming in the established disaster response. This requirement is not unexpected, given that the disruptive emergent system vignettes were selected based on the ability of a system to supplement, displace, or fill gaps in the established response. However, this gap need not be recognized by the established response system but identified by would-be developers of disruptive emergent systems. Indeed, the federal response system recognizes that initial response gaps will exist, particularly during hurricane responses. This condition represents survivor-driven demands. The second condition encompasses the capabilities, or lack thereof, and organizational structures available. In these cases, the disruptive systems emerged in response to the perceived lack of capability within the established response system to perform certain activities. The ability to act in a decentralized and agile manner was a common feature of the disruptive emergent system structures. This organization structure was a distinct contrast from the hierarchy within the established response system. These conditions represent supply that can meet survivor demands.

The disruptive emergent systems within the Hurricane Katrina response also required two specific types of motivation. The first includes specific community features, such as community-based resilience, solidarity, and community-centric attitudes. These community features drive the actions taken based on the perceived response gaps. These motivations are supplied to the disruptive response system. The second is the reaction to

the perceived slow response actions from the established response system. This motivation represents a demand for more timely response, particularly to urgent survivor needs.

The features within these conditions and motivations merged to form the disruptive emergent systems observed. The conditions and motivations are visually represented as an ontological diagram in Figure 2. The conditions are shown in the upper two quadrants and motivations in the lower quadrants. The left side of the diagram represents demands within the disaster environment and the right represents supply. The demands that drove the disruptive emergent systems within the Hurricane Katrina response were all survivor-centric. That is, the survivor needs were the necessary demand signals required to develop the disruptive emergent systems. The supply components enabled the disruptive systems to attempt to satisfy those demand signals within the disaster response. The general feature categories make up the inner-most ring around the disruptive emergent system. The features identified through this analysis reside in the middle ring within the appropriate quadrant. Example feature components are within the outermost ring surrounded by a dashed line. The colors distinguish the quadrants and features for illustrative purposes.

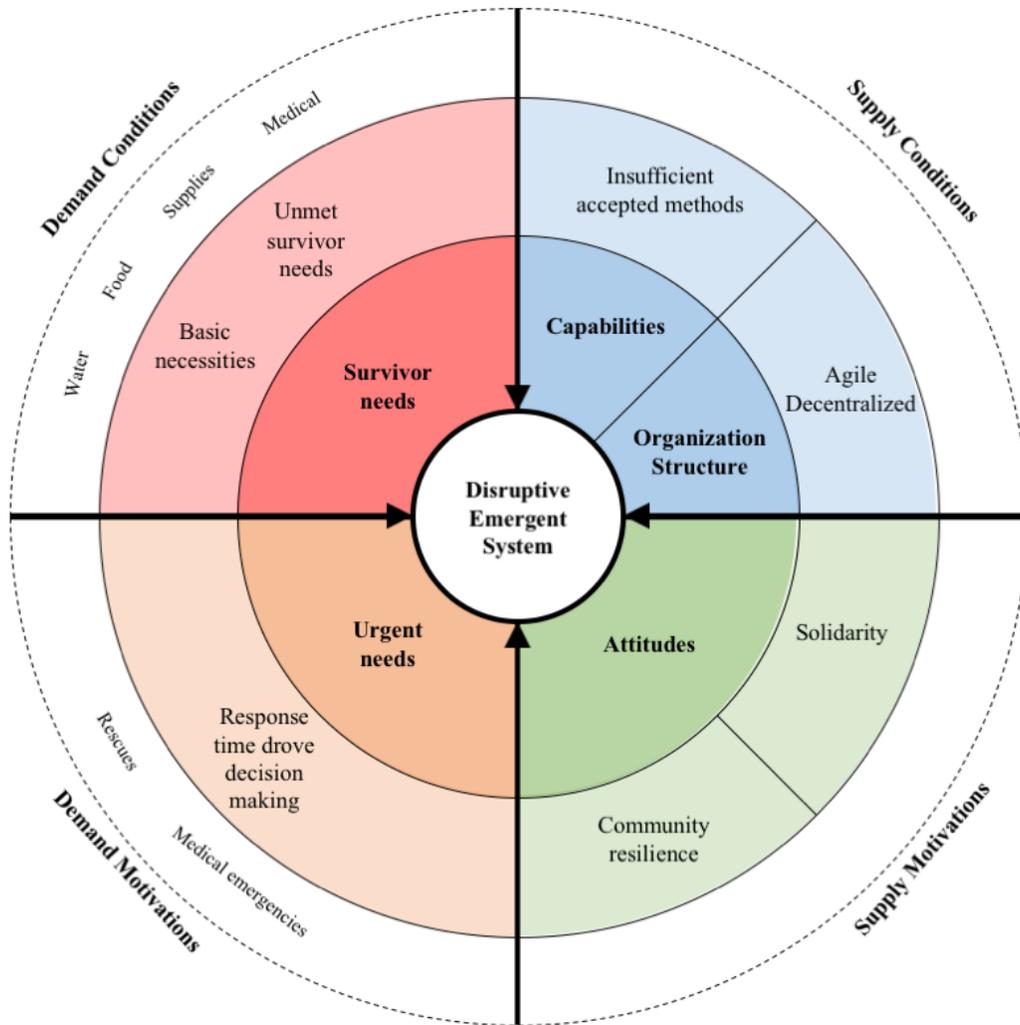


Figure 2. Disruptive emergent system ontological diagram for Hurricane Katrina vignettes.

These disruptive emergent systems supplemented or filled ESFs #6 Mass Care, Emergency Assistance, Temporary Housing, and Human Services, #8 Public Health and Medical Services and #9 Search and Rescue. The supported core capabilities were #9 Mass Care Services, #10 Mass Search and Rescue Operations and #14 Public Health, Healthcare, and Emergency Services. This set of three ESFs and three core capabilities are focused on providing lifesaving services and sustaining life through the response phase and into the disaster recovery. These ESFs and core capabilities are distinctly survivor-centric and reflect the five properties and features identified through this analysis.

It may seem that the properties and features could be confounded in this analysis by the ESFs and core capabilities as a form of confirmation bias. It is important to identify the differences that underlie the properties and features identified through the grounded theory approach and the predefined ESFs and capabilities. The ESFs and core capabilities are actions that need to be completed during a disaster response. These actions identify what needs to be done. The disruptive emergent systems studied through this research were identified by these actions. However, the properties and features reveal why and how these actions were completed by a disruptive emergent system rather than the established response system.

Overall, the properties and features identified for the studied Hurricane Katrina disruptive emergent systems set the stage for disruptive emergence during disaster response. The disruptive emergent systems analyzed required a certain level of community resilience to begin. Without community resilience, in this case in the form of solidarity, these disruptive emergent systems would not have materialized. The conditions of the response required an actionable gap that could be filled, such as the perception of a slow or inadequate established response. These conditions were necessary for the disruptive emergent systems to appear. An agile and decentralized disruptive emergent system is able to respond to and fill the actionable gaps. This feature describes how a disruptive emergent system may be able to operate within the disaster response environment.

V. HURRICANE SANDY

Hurricane Sandy struck the Atlantic coast of southern New Jersey on October 29, 2012, as a post-tropical cyclone after traveling up the East Coast as a Category 1 hurricane. Sandy caused widespread flooding through coastal communities in New Jersey and New York along with severe wind damage and area-wide power outages.⁶⁰ Fires destroyed some communities, in part because local fire services could not be notified or were unable to respond. Over 600,000 homes were impacted in New York and New Jersey.⁶¹ After the storm, a small group of volunteers went door-to-door in affected communities to determine what storm survivors needed most. The volunteers discovered a distinct lack of governmental or NGO response in some neighborhoods. These volunteers soon mobilized a large volunteer force to fill the observed gaps in relief and emerged as Occupy Sandy. These initial volunteers, veterans of the Occupy Wall Street protest in New York, were adept at mobilizing and organizing. Social technologies enabled much of the rapid mobilization, volunteer deployment, and donation collection. On the ground, however, in distribution and donation centers or on delivery runs, different types of organizations emerged to meet the needs of storm survivors. Occupy Sandy's efforts supplemented the federal response in several different emergent areas.

A. OCCUPY SANDY

The Occupy Sandy movement started with a few well-intentioned individuals. They visited public housing in the Rockaways and Red Hook to discover unmet needs and deliver supplies and food.⁶² These volunteers realized that a larger group would be necessary to satisfy a fraction of the needs in these neighborhoods. These few original volunteers leveraged the rapidly deployable Occupy Wall Street network and the

⁶⁰ Federal Emergency Management Agency, *Hurricane Sandy FEMA After-Action Report* (FEMA, July 1, 2013), https://www.fema.gov/media-library-data/20130726-1923-25045-7442/sandy_fema_aar.pdf, iii.

⁶¹ Ambinder et al., "The Resilient Social Network," 23–24.

⁶² Alan Feuer, "Where FEMA Fell Short, Occupy Sandy Was There," *The New York Times*, November 9, 2012, <https://www.nytimes.com/2012/11/11/nyregion/where-fema-fell-short-occupy-sandy-was-there.html>; and MacFarquhar, "Occupy Sandy."

experiences of those involved to mobilize a volunteer force that eventually grew to 60,000.⁶³ The Occupy Sandy network rapidly organized donation and distribution centers, food preparation groups, digital information coordination teams, motor pools, and pumping and demolition crews.⁶⁴

The Occupy Sandy organization attempted to integrate into the government-organized response efforts with other NGOs. However, the connection to Occupy Wall Street was initially a hindrance on those efforts. The established organizations within the response organizational structure initially rejected Occupy Sandy based on those connections and assumed motivations. However, after the Occupy Sandy network demonstrated effective response in Red Hook and the Rockaways, the government response structure began to take notice.⁶⁵ The Occupy Sandy network maintained an extensive awareness of those neighborhoods and provided valuable “ground truth” information to government response organizations.⁶⁶ The Occupy Sandy movement exhibited agility throughout the response and efficiently transitioned to recovery once immediate survivor needs were met. Through the response phase, Occupy Sandy emerged to fill several federal Emergency Support Functions, including ESF #5: Information and Planning, ESF #6 Mass Care, Emergency Assistance, Temporary Housing, and Human Services, ESF #7 Logistics, and ESF #15 External Affairs. By filling these support functions, Occupy Sandy supported federal core capabilities #1 Planning, #2 Public Information and Warning, #3 Operational Coordination, #9 Mass Care Services, and #13 Logistics and Supply Chain Management.

Occupy Sandy filled some immediate gaps in the government’s response and continued to expand abilities and services. As more needs became apparent or evolved over the response, Occupy Sandy was able to quickly pivot and adapt. Response organizations

⁶³ Ambinder et al., “The Resilient Social Network,” 24–25.

⁶⁴ Feuer, “Where FEMA Fell Short, Occupy Sandy Was There”; MacFarquhar, “Occupy Sandy”; Ambinder et al., “The Resilient Social Network”; and Kilkenny, “Occupy Sandy Efforts Highlight Need for Solidarity, Not Charity.”

⁶⁵ Ambinder et al., “The Resilient Social Network,” 40.

⁶⁶ Kilkenny, “Occupy Sandy Efforts Highlight Need for Solidarity, Not Charity.”

like the American Red Cross and the National Guard began distributing supplies to Occupy Sandy, whose members were considered area experts by other agencies. Federal and associated agencies deferred to Occupy Sandy's expertise in a de facto recognition of the movement's legitimacy and value to disaster response. Occupy Sandy had three major effects on the established response system. First, the actions of Occupy Sandy forced the federal response system to realize that a group of volunteers can "spontaneously" create a large-scale response network.⁶⁷ Second, Occupy Sandy success led federal response leaders to acknowledge that sometimes a non-traditional response group may be the best for the community.⁶⁸ Finally, Occupy Sandy success led to increased trust over the established system.⁶⁹

B. SOCIAL TECHNOLOGIES

Occupy Sandy used social technologies as self-organizing tools for the Hurricane Sandy response. Initial messages on Twitter started the self-organization wave that developed into Occupy Sandy.⁷⁰ Various tools beyond Twitter were used, depending upon the needs of storm survivors. For example, calls for volunteers went out over Twitter while calls for return volunteers, or volunteers who signed up for the distribution list, were posted to cellular texting applications.⁷¹ Volunteers developed a website to publish information for storm survivors and volunteers.⁷² Other volunteers set up and maintained an online wedding registry through Amazon.com to solicit specific donations based on donation center inventories and needs identified in the community.⁷³ Using these social

⁶⁷ Ambinder et al., "The Resilient Social Network," 39–41.

⁶⁸ Ambinder et al., 42.

⁶⁹ Ambinder et al. 3, 52, 67.

⁷⁰ MacFarquhar, "Occupy Sandy"; Kilkenny, "Occupy Sandy Efforts Highlight Need for Solidarity, Not Charity"; and Occupy Sandy, "@OccupySandy," Twitter, n.d., <https://twitter.com/search?l=&q=from%3Aoccupysandy%20since%3A2012-10-24%20until%3A2012-12-31&src=typd>.

⁷¹ Ambinder et al., "The Resilient Social Network," 31–32.

⁷² Occupy Sandy Recovery, "Occupy Sandy Recovery," accessed October 12, 2018, <http://occupysandy.net/>.

⁷³ Megan Garber, "Occupy Sandy Hacks Amazon's Wedding Registry (in a Good Way)," *The Atlantic*, November 5, 2012, <https://www.theatlantic.com/technology/archive/2012/11/occupy-sandy-hacks-amazons-wedding-registry-in-a-good-way/264543/>.

technologies allowed Occupy Sandy to reach a wide volunteer audience, that enabled the immediate response on the ground and remote participation through donations and organizing efforts.

By using additional social technologies beyond telephone and email communications, Occupy Sandy was able to maintain regular contact with volunteers to provide essential services to survivors through the response phase. Using these social technologies to organize and mobilize a volunteer force that eventually grew to roughly 60,000 allowed Occupy Sandy to supplement the federal government's ESF #5 Information and Planning, ESF #7 Logistics, and ESF #15 External Affairs. The core capabilities that were supported by these ESFs are #1 Planning, #2 Public Information and Warning, #3 Operational Coordination, and #13 Logistics and Supply Chain Management.

The major effect social technologies had on the established disaster response system was demonstrate how those technologies could facilitate volunteer organization, logistics coordination, and timely information dissemination. Social technologies enabled volunteer networks to operate in an agile manner. Rapid dissemination of information to an engaged volunteer network via social technologies allowed Occupy Sandy to scale up operations as needed. Operational scaling allowed for efficient, agile response operations that tended to adjust faster to information than the established response system. Social technologies encouraged a flat network throughout Occupy Sandy which contrasted with the structured hierarchy of the federal response system. Rapid adjustments to services were sometimes necessary to respond to survivor needs.

The main effects on the established disaster response system from Occupy Sandy and its use of social technologies are threefold. First, Occupy Sandy served as a large-scale proof-of-concept for wide-area, decentralized, volunteer managed response operations. The successes that Occupy Sandy had throughout the response were noticed by the federal response system. The Homeland Security Studies & Analysis Institute's study on Occupy Sandy was commissioned by the DHS Science and Technology Directorate to attempt to understand these successes.⁷⁴ Second, Occupy Sandy showed that social technologies

⁷⁴ Ambinder et al., "The Resilient Social Network," 5.

could be used to organize decentralized operations without reliance upon a structured hierarchy. The DHS Virtual Social Media Working Group and First Responders Group jointly reviewed the use of social technologies during the Hurricane Sandy response.⁷⁵ Finally, the successes enjoyed by Occupy Sandy provided clear benefits to storm survivors but also served to reduce survivors’ trust in the federal response system.⁷⁶

C. INSIGHTS AND ANALYSIS

The two vignettes from the Hurricane Sandy response, the Occupy Sandy movement and social media organizing, revealed an aggregate 103 codes. As in the Hurricane Katrina analysis, the coded vignette data were condensed to create properties and features within each vignette that were carried over to the next vignette analysis. These codes revealed eight specific properties and features of the analyzed disruptive emergent systems within the Hurricane Sandy response. The evolution of the properties and features from the first vignette to the final is shown in Table 3.

Table 3. Evolution of disruptive emergence properties and features through the Hurricane Sandy analysis.

Initial Vignette Features	Final Vignette Features
Urgent / unmet needs	Urgent / unmet survivor needs
Volunteer humanitarianism	Volunteer humanitarianism
Accepted routes / methods / procedures	Use of accepted routes / methods / procedures
Grassroots organization	Grassroots organizing abilities
Response time / action	Rapid response time / useful actions
Creative problem solving	Creative problem solving
Leverage technology	Capability to leverage technology
Community resilience	Supportive external community resilience

⁷⁵ U.S. Department of Homeland Security, Virtual Social Media Working Group and DHS First Responders Group, *Lessons Learned: Social Media and Hurricane Sandy* (June 2013), 4–5.

⁷⁶ Ambinder et al., “The Resilient Social Network,” 67–69.

The initial coding revealed eight conditions and features of this disruptive emergent system within the hurricane response.

- *Urgent / unmet needs* incorporated all survivor needs that were urgent or not met. This feature is a condition of the response environment and represents a gap in response coverage or an unacceptable response time.
- *Volunteer humanitarianism* reflected the necessity of these disruptive emergent systems. Without volunteers bearing humanitarian tendencies, many survivor needs would not be met.
- *Accepted routes, methods, and procedures* encompassed the codes that captured methods and procedures used by the established response system, NGOs, and commercial companies. These codes include process failures along with new processes developed through the disruptive emergent system.
- *Grassroots organization* collected those codes that described the organization structure, actions, and motivations within the disruptive emergent system.
- *Response time / action* incorporated the collective codes that describe the response actions taken by the disruptive emergent system before or in place of the established response system.
- *Creative problem solving* captured the various methods and ideas implemented by the disruptive emergent system to meet survivor needs.
- *Leverage technology* was tied directly to creative problem solving. The disruptive emergent system was very successful at leveraging technology for a variety of organizational and operational tasks, occasionally creatively solving problems.

- *Community resilience* was essential to disaster response in several affected areas. The number of volunteers, donations, facilities, support missions, and solutions enabled through the disruptive emergent system are all captured in this feature.

The final coding of the Hurricane Sandy disruptive emergent systems served to refine the eight conditions and features identified in the first iteration of coding analysis.

- The first feature was refined to *urgent / unmet survivor needs* to specify that this feature is a condition of the response focused solely on survivors.
- *Volunteer humanitarianism* was expanded to include remote volunteers, enabled through social technologies and online platforms.
- *Use of accepted routes / methods / procedures* was modified to reflect the ways in which accepted methods and procedures were used within the disruptive emergent systems. In other words, this feature captured how accepted routes, methods, and procedures were or were not used throughout the response within the studied disruptive emergent systems.
- One definitive feature of the disruptive emergent systems studied is *grassroots organizing abilities*. These abilities were essential to engaging volunteers to deliver need supplies and services.
- The *rapid response time / useful actions* feature was refined from the initial analysis to specify rapidity of response and the usefulness of actions by the disruptive emergent systems for survivors. This key feature allows for increased survivor trust in the disruptive emergent systems while increasing its legitimacy in terms of the whole emergency response system.
- *Creative problem solving* had no substantive changes from the first iteration of features, though additional coded evidence was collected.

- The refinement of the seventh feature to *capability to leverage technology* was an important distinction for disruptive emergent systems. Possessing the capability to leverage technology to help survivors captured the innovative and emergent methods used by the disruptive emergent systems to accomplish response-related missions.
- *Supportive external community resilience* encapsulated the efforts of the surrounding, external communities to support affected communities. This feature includes virtual communities that provide support but may not be physically located in the affected area.

The features identified through this analysis are concentrated into several categories. The first is motivation. *Urgent and unmet survivor needs* along with attitudes of *volunteer humanitarianism* combined to create a strong motivator for the volunteers of these disruptive emergent systems. Motivations based on survivor needs can be classified as demand signals. Volunteer humanitarianism and supportive external community resilience are motivational features necessary to be supplied to the system. The second category is organization and structure. These disruptive emergent systems leveraged an existing network of motivated people to create the initial organization. The agile and decentralized grassroots structure allowed the organization to expand into needed operations near the disaster site and virtually. This structure also promoted creative problem solving and using existing resources to maximize impact for survivors. The third category is capability. A wide array of capabilities existed within these disruptive emergent systems, allowing volunteers to *leverage technology*, provide *rapid response with useful actions*, and *use accepted routes, procedures and methods* for unconventional response action support. These capability-focused features were necessary for many of the solutions and actions conducted through these disruptive emergent systems.

The feature categories described can be examined in terms of the conditions, motivations, supply and demand ontology described in the Hurricane Katrina analysis. The same ontological framework was applied to Hurricane Sandy, represented in Figure 3. The *urgent and unmet survivor needs* feature was split between conditions and motivations.

This differentiation was necessary to accurately reflect unmet needs as a feature of the disaster response, while urgent needs served as motivators for the disruptive system. Some needs within this feature could fall into both conditions and motivations. Simply put, conditions reflect the status of a particular needs while motivations reflect the urgency of the need. *Volunteer humanitarianism* and *supportive external community resilience* formed collective attitudes as motivations supplied to the disaster response and disruptive emergent system. Capabilities and organizational structures are conditions that provide input to the supply side of disaster response.

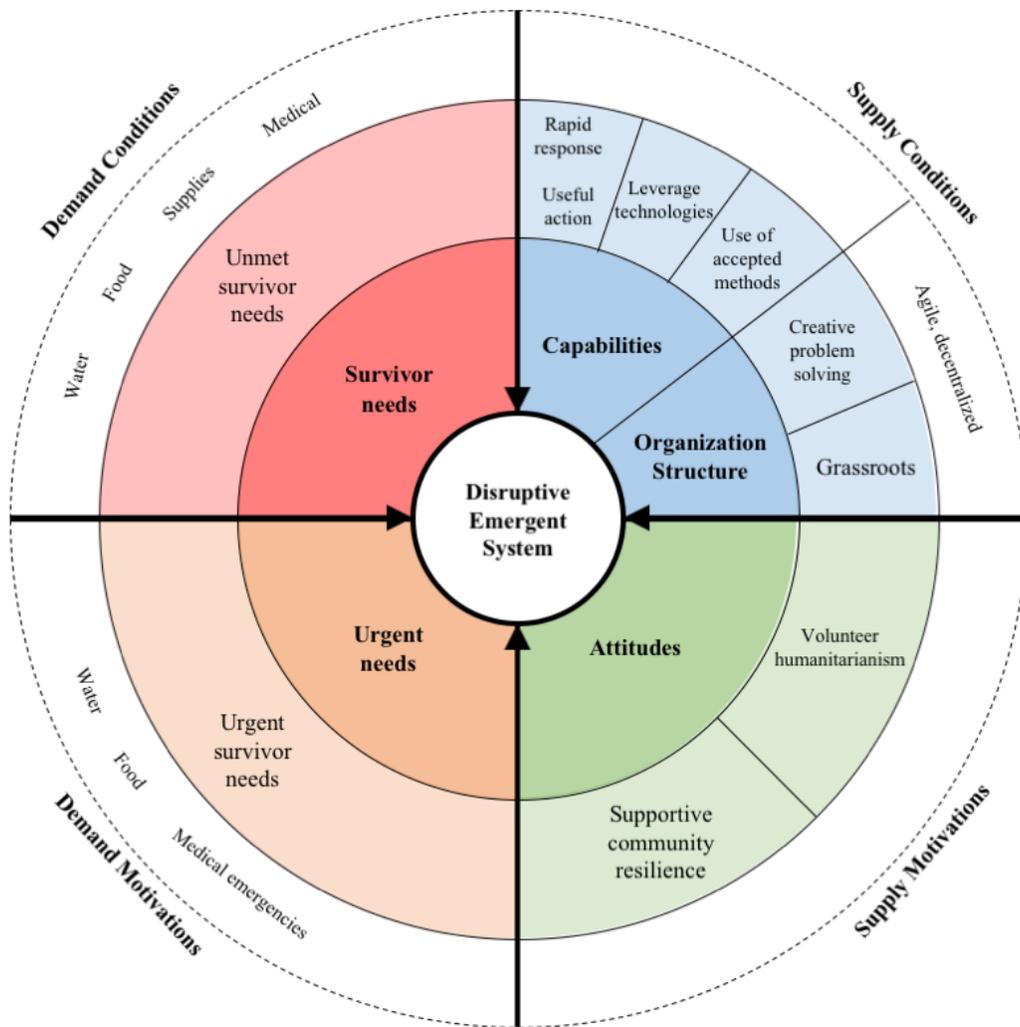


Figure 3. Disruptive emergent system ontological diagram for Hurricane Sandy vignettes.

These disruptive emergent systems supplemented or filled ESFs #5: Information and Planning, ESF #6 Mass Care, Emergency Assistance, Temporary Housing, and Human Services, ESF #7 Logistics, and ESF #15 External Affairs. The core capabilities supported through these functions were #1 Planning, #2 Public Information and Warning, #3 Operational Coordination, #9 Mass Care Services, and #13 Logistics and Supply Chain Management. These ESFs and core capabilities are focused on the organization, communication, and logistics needs required to provide mass services for survivors. Essentially, each function and capability targeted supporting survivors and providing necessities.

The features identified through the constant comparative grounded theory approach and the resultant categories reveal why the disruptive system emerged during the Hurricane Sandy response and how the system was able to be disruptive. Volunteers with strong motivation to help survivors quickly began developing emergent systems to fill perceived response gaps. To fill the perceived gaps in mass care functions, large-scale, emergent organizational structures were developed with a particular focus on technology leverage points. Technological capabilities within the disruptive emergent systems drove the methods used to fill perceived response gaps. These technological capabilities, like social technology use, were used to organize volunteers, communicate within the network, and disseminate information to the public. Social technologies were also used to activate external community resilience through virtual efforts, which promoted more community resilience within the affected area.

VI. HURRICANE HARVEY

Hurricane Harvey struck the Gulf Coast of Texas near Rockport on August 25, 2017, causing extreme and widespread flooding through Houston and the surrounding metro area. After the storm, roughly 95 percent of cellular towers remained online to provide service to customers along the Texas coast.⁷⁷ Survivors were able to use mobile devices to call for help, but the more than 75,000 calls overran public safety call centers in the first 24 hours.⁷⁸ Long hold times caused survivors to give up on calling 9-1-1 and turn to social media platforms like Facebook, Twitter, and Instagram for help.⁷⁹ Requests for help were directed to first-responder organizations, friends, and others online. Social media users took notice of these requests and the response was rapid and dynamic. Online volunteers mobilized a vast array of individuals around the world to track and aggregate posts, push information to volunteer responders, call 9-1-1 on behalf of those in need, and mark individuals as safe after victims were rescued.⁸⁰ This process occurred with little to no formalized organizational structure and depended completely on

⁷⁷ Jon Brodtkin, “Tropical Storm Harvey Takes Out 911 Centers, Cell Towers, and Cable Networks,” *Ars Technica*, August 28, 2017, <https://arstechnica.com/information-technology/2017/08/tropical-storm-harvey-takes-out-911-centers-cell-towers-and-cable-networks/>.

⁷⁸ Associated Press, “‘Hell’s Breaking Loose’: A 911 Center under Siege by Harvey,” *Omaha World-Herald*, August 30, 2017, http://www.omaha.com/news/nation/hell-s-breaking-loose-a-center-under-siege-by-harvey/article_7712a312-8dbd-11e7-8e17-cfc2cdf67f17.html.

⁷⁹ Chelsea Bailey, “#SOSHouston: How Apps and Social Media Assist Harvey Rescue Efforts,” *NBC News*, August 31, 2017, <https://www.nbcnews.com/storyline/hurricane-harvey/soshouston-how-apps-social-media-assist-harvey-rescue-efforts-n797841>; Silverman, “Facebook, Twitter Replace 911 Calls for Stranded in Houston”; Koren, “Using Twitter to Save a Newborn from a Flood”; and Laura J. Nelson, “In Houston, Pleas for Help Go Out over Social Media: ‘Please Send Help. 911 Is Not Responding,’” *Los Angeles Times*, August 27, 2017, <http://www.latimes.com/nation/la-na-houston-harvey-911-20170827-story.html>.

⁸⁰ Bailey, “#SOSHouston: How Apps and Social Media Assist Harvey Rescue Efforts”; Gilmer, “During Harvey, Social Media Rose to the Challenge as a Force for Good”; Ciechalski, “Louisiana’s ‘Cajun Navy’ Rushes to Texas to Help Rescue People from the Floodwaters”; “Houston Harvey Rescue,” Houston Harvey Rescue, accessed October 18, 2017, <http://houstonharveyrescue.com/>; and Koren, “Using Twitter to Save a Newborn From a Flood.”

volunteers, most of whom had not met the individuals they were assisting.⁸¹ These emergent systems supplemented federal, state, and local responses in several key areas.

A. CAJUN NAVY

The Cajun Navy reappeared in the Hurricane Harvey response, due in part to a strong connection between the city of Houston and Louisianans displaced by Hurricane Katrina.⁸² People identifying as part of the Cajun Navy responded in organized groups or as unorganized collectives to enter the floodwaters to rescue trapped survivors.⁸³ Besides trucks and boats, the Cajun Navy relied heavily on mobile and social technologies, particularly Facebook, Twitter, Zello, and Google.⁸⁴ Calls for assistance posted to Facebook or Twitter were mapped by volunteers on a Google map-enabled website called Houston Harvey Rescue.⁸⁵ Additional volunteers acted as dispatchers using the radio-like Zello app to send rescue boats to particular locations. Rescuers on boats would use Google Maps to navigate and Zello to coordinate and inform the volunteer dispatchers when individuals were rescued. Over 7,800 individuals were marked rescued and safe through this process.⁸⁶

The collection of individuals and groups known as the Cajun Navy were again credited with saving many lives. Unlike the Hurricane Katrina response, rapidly deployable communications and open source technology were available for members of the Cajun Navy to modify and use for rescue operations. These technologies allowed remote data

⁸¹ Ciechalski, “Louisiana’s ‘Cajun Navy’ Rushes to Texas to Help Rescue People from the Floodwaters”; Gilmer, “During Harvey, Social Media Rose to the Challenge as a Force for Good”; and “Houston Harvey Rescue.”

⁸² Emily Wax-Thibodeaux, “‘Cajun Navy’ Races from Louisiana to Texas, Using Boats to Pay It Forward,” *Washington Post*, August 28, 2017, https://www.washingtonpost.com/national/cajun-navy-races-from-louisiana-to-texas-using-boats-to-pay-it-forward/2017/08/28/1a010c8a-8c1f-11e7-84c0-02cc069f2c37_story.html.

⁸³ Wax-Thibodeaux, “‘Cajun Navy’ Races from Louisiana to Texas, Using Boats to Pay It Forward”; and Markowitz, “Hurricane Harvey and Our Vigilante Future of Disaster Relief.”

⁸⁴ Selena Larson, “Stranded Hurricane Survivors Use Zello App to Get Help,” *CNNMoney*, August 28, 2017, <http://money.cnn.com/2017/08/28/technology/volunteers-harvey-rescue-apps/index.html>.

⁸⁵ Larson, “Stranded Hurricane Survivors Use Zello App to Get Help”; Ciechalski, “Louisiana’s ‘Cajun Navy’ Rushes to Texas to Help Rescue People from the Floodwaters”; and “Houston Harvey Rescue.”

⁸⁶ “Houston Harvey Rescue.”

collection and rescue boat dispatch, increasing the number of remote volunteers while increasing the level of coordination for rescues. The Cajun Navy's rescue efforts supplemented the federal government's ESF #5 Information and Planning and ESF #9 Search and Rescue. The core capabilities supported by these ESFs are #10 Mass Search and Rescue Operations and #15 Situational Assessment. Interestingly, two other core capabilities were supported through the Cajun Navy's actions but not through defined ESFs, including #3 Operational Coordination and #4 Critical Transportation.

The Cajun Navy has responded to flood disasters along the Gulf Coast since the Hurricane Katrina response. Since that time, the established disaster response system has grown accustomed to Cajun Navy operations. During the Hurricane Katrina response, members of the Cajun Navy were turned away from flood areas by law enforcement and threatened with jail time if they defied orders.⁸⁷ For the Hurricane Harvey response, the local officials requested willing boat operators to assist in the rescue operations.⁸⁸ The established response system's acceptance of this ad hoc volunteer group has changed over the intermediate 12 years from a potential liability to a force multiplier.

B. INDIVIDUAL SOCIAL MEDIA REQUESTS

After the storm, many survivors found they were still able to connect to the cellular network which allowed calls and connectivity.⁸⁹ However, the extensive use of the network and overloaded call centers made phone calls difficult for many. Dropped calls, long hold times, and diminished battery life caused survivors to seek help using different methods including posting to social media platforms.⁹⁰ Online platforms like Facebook, Twitter, Instagram, and Nextdoor were used by survivors, unaffected friends and family,

⁸⁷ Gunn, "Greatest Story Never Told."

⁸⁸ Nelson, "In Houston, Pleas for Help Go out over Social Media: 'Please Send Help. 911 Is Not Responding.'"

⁸⁹ Brodtkin, "Tropical Storm Harvey Takes out 911 Centers, Cell Towers, and Cable Networks."

⁹⁰ Heather Kelly, "Harvey Highlights Shortcomings of Aging 911 Technology," *CNNMoney*, September 1, 2017, <http://money.cnn.com/2017/09/01/technology/future/911-tech-harvey/index.html>; Nelson, "In Houston, Pleas for Help Go out over Social Media: 'Please Send Help. 911 Is Not Responding'"; and Silverman, "Facebook, Twitter Replace 911 Calls For Stranded In Houston."

and volunteers to request help individuals stranded by floodwaters.⁹¹ Posts were re-posted, calls were made in response to posts and response maps were developed using posts.⁹² However, this use of social media platforms was not expected by response agencies, let alone the volume of requests posted. Several response agencies requested survivors do not post assistance requests on social media platforms and rely entirely on calling 9-1-1 or other emergency numbers.⁹³ These requests were due to the fact that the established response agencies were not prepared, staffed, or equipped to respond via social media platforms. Despite these requests, survivors continued to post. Volunteer groups like the Cajun Navy and Humanity Road used the posts to develop crisis maps for various response groups, both government and volunteer.

The resilient communications infrastructure enabled continued connectivity through mobile devices, despite widespread flooding in the Houston metro area. The resiliency allowed survivors to reach out for help using several forms of mobile technology. In many cases, individuals quickly determined that posting an assistance request may be the only chance to broadcast a message. This solution became pervasive as survivors collectively turned to social media to request and provide help. By moving emergency communications into the social media arena, survivors inadvertently expanded communication capacity, supporting ESF #2 Communications. The core capability supported through this solution and ESF was #12: Operational Communications.

Agencies within the established response system demonstrated the capability to push information to the public through social media platforms but limited ability to respond to direct requests. Several used Twitter to instruct people in need of assistance to call 9-1-

⁹¹ Silverman, “Facebook, Twitter Replace 911 Calls For Stranded In Houston.”

⁹² Nelson, “In Houston, Pleas for Help Go out over Social Media: ‘Please Send Help. 911 Is Not Responding’”; Gilmer, “During Harvey, Social Media Rose to the Challenge as a Force for Good”; and Bailey, “#SOSHouston: How Apps and Social Media Assist Harvey Rescue Efforts.”

⁹³ Gilmer, “During Harvey, Social Media Rose to the Challenge as a Force for Good”; and Silverman, “Facebook, Twitter Replace 911 Calls For Stranded In Houston.”

1 despite the potentially long wait times.⁹⁴ This disruptive emergent solution forced agencies within the established response system to consider social media requests as a legitimate communications channel for individual emergencies.⁹⁵ Ed Gonzalez, the Harris County sheriff, personally followed up with some social media requests.⁹⁶ Data on rescues attributed to social media notification is unavailable beyond anecdotes.

C. VIRTUAL VOLUNTEERS

Many people following the disaster through news reports also monitored social media and took active roles in responding to requests. Friends and family responded to calls for help by re-posting or calling 9-1-1 on behalf of the survivor.⁹⁷ Other social media users did the same for complete strangers. Some users, part of organized virtual groups like Humanity Road or CrowdRescue HQ, combed through social media to collect assistance requests for geo-located crisis maps.⁹⁸ Tools like the online Houston Harvey Rescue database were rapidly developed to dispatch volunteer rescuers and track the rescue of flood victims.⁹⁹ Zello, the walkie-talkie like app, was used extensively by the online contingent of the Cajun Navy to rapidly disseminate rescue information.¹⁰⁰ Nearly all of these activities were performed by virtual volunteers outside of the Houston area.

⁹⁴ Nelson, “In Houston, Pleas for Help Go out over Social Media: ‘Please Send Help. 911 Is Not Responding’”; Kelly, “Harvey Highlights Shortcomings of Aging 911 Technology”; Koren, “Using Twitter to Save a Newborn From a Flood”; and Shu, “Coast Guard Asks People Stranded by Harvey to Call Them Instead of Posting on Social Media for Help.”

⁹⁵ Nicole Ogrysko, “Recent Hurricanes Have the Coast Guard Rethinking Social Media’s Role in Rescue and Response,” *Federal News Radio*, September 21, 2017, <https://federalnewsradio.com/management/2017/09/recent-hurricanes-ha...e-coast-guard-rethinking-social-medias-role-in-rescue-and-response/>.

⁹⁶ Koren, “Using Twitter to Save a Newborn From a Flood.”

⁹⁷ Nelson, “In Houston, Pleas for Help Go out over Social Media: ‘Please Send Help. 911 Is Not Responding’”; and Gilmer, “During Harvey, Social Media Rose to the Challenge as a Force for Good.”

⁹⁸ “Hurricane Harvey Resources”; and CrowdRescue HQ, “CrowdRescue HQ,” accessed November 15, 2017, <http://www.crowdrescuehq.org/>.

⁹⁹ “Houston Harvey Rescue.”

¹⁰⁰ Ciechalski, “Louisiana’s ‘Cajun Navy’ Rushes to Texas to Help Rescue People from the Floodwaters.”

The wide array of emergent solutions coalesced to address the massive influx of information transmitted through social media platforms. These solutions supplemented, and in some cases directly supported, the federal government’s ESF #5 Information and Planning and ESF #9 Search and Rescue. The core capabilities supported include #3 Operational Coordination, #10 Mass Search and Rescue Operations, and #15 Situational Assessment.

Virtual volunteers have been a part of the established disaster response system for some time. Many of these volunteers are part of an organization within the VOAD network.¹⁰¹ Virtual VOAD volunteers can be a large force multiplier when activated. In the case of the Hurricane Harvey response, some volunteers were part of a VOAD that had a specific mission or specific agency as the information consumer. However, many volunteers were not part of a VOAD and acted independently or coalesced into self-organized roles, such as the volunteers who populated the Houston Harvey Rescue database and crisis map. Two clear effects on the established response system were observed about virtual volunteers. The first is that virtual volunteer model expanded volunteer opportunities to anyone with time and a network connection. This model leveraged off-site, crowdsourced information to develop actionable crisis maps for on-scene responders. This approach is considerably different than the centralized information collection and aggregation teams within an EOC. The second effect is a major paradigm shift for volunteer management. While virtual VOADs have existed for several years, virtual volunteers who “just show up” cannot be managed the same way as a volunteer arriving at a disaster site. This is particularly true when virtual volunteers generate solutions outside of a VOAD platform, much like the Houston Harvey Rescue solution.

D. UNITED STATES COAST GUARD ACADEMY

Cadets at the United States Coast Guard Academy (USCGA) recognized an assistance request gap in the Coast Guard’s response capability. Several methods are available to request assistance or aid from the Coast Guard. Individuals may hail the USCG

¹⁰¹ For example, Humanity Road <https://www.humanityroad.org/>.

using VHF (Very High Frequency) radio Channel 16, or 156.8 MHz. Channel 16 is the international maritime hailing and distress channel and is monitored constantly by USCG units across the country. The second method is calling 9-1-1 or the nearest USCG Command Center directly via telephone. The third method, though not endorsed by the USCG for distress purposes, includes email or text message notifications.¹⁰² Cadets identified the notable absence of any other form of digital communication, such as social media, within these methods. To counter this gap, cadets partnered with the Digital Humanitarian Network and Humanity Road to gather information from social media channels for geo-located crisis maps specifically for Coast Guard responders.¹⁰³ This partnership resulted in the USCGA Digital Humanitarian Team.

The cadet team was responsible for parsing, formatting, and visually presenting all the data gathered by virtual volunteers.¹⁰⁴ The resulting crisis response maps and associated data were used by Coast Guard responders and command centers, despite being unsolicited. This solution supplemented the accepted assistance request methods which expanded the communication channels available to flood survivors. Though cadets-run Digital Humanitarian Team is part of the federal government's response in this case, the solution initially was not. This solution supplemented efforts of the Coast Guard's Geospatial Intelligence unit who assembled response maps based on 9-1-1 calls delivered from Houston.¹⁰⁵ By creating partnerships and developing crisis maps, the cadets

¹⁰² U.S. Coast Guard, *U.S. Coast Guard Addendum to the United States National Search and Rescue Supplement (NSS) to the International Aeronautical and Maritime Search and Rescue Manual (IAMSAR) COMDTINST M16130.2F*, January 2013, <http://www.dco.uscg.mil/Portals/9/CG-5R/manuals/COMDTINST%20M16130.2F.pdf>. 2–28, 2–35, 2–41, 2–43.

¹⁰³ Stefanie Senkow, "CGA and Humanity Road Use Social Media To Save Lives," United States Coast Guard Academy, June 27, 2018, <https://www.uscga.edu/page.aspx?id=1699>; Meg McIntyre, "Keene High Grad in Coast Guard Academy Helps Hurricane Harvey Response Efforts," *Keene Sentinel*, September 5, 2017, https://www.sentinelsource.com/news/local/keene-high-grad-in-coast-guard-academy-helps-hurricane-harvey/article_b78b59d1-e6fd-55a1-908b-b1efd2a16619.html; Associated Press, "Coast Guard Academy Cadets Create Maps for Harvey Response," *U.S. News & World Report*, August 31, 2017, <https://www.usnews.com/news/best-states/connecticut/articles/2017-08-31/coast-guard-academy-cadets-create-maps-for-harvey-response>; and Evan Twarog, "Searching for the Pulse of Technology," TEDxYale, video, 11:00, March, 2018, <https://www.youtube.com/watch?v=W63s1L5hMco&t=522s>.

¹⁰⁴ McIntyre, "Keene High Grad in Coast Guard Academy Helps Hurricane Harvey Response Efforts."

¹⁰⁵ Office of the Director of National Intelligence, "The Water Kept Rising: How Coast Guard Intelligence Mapped Hurricane Impact," Intel.gov, accessed October 13, 2018, <https://www.intel.gov/mission/intel-stories/576-the-water-kept-rising>.

supplemented ESF #5 Information and Planning and ESF #9 Search and Rescue. As in the virtual volunteers vignette, the supported core capabilities include #3 Operational Coordination, #10 Mass Search and Rescue Operations, and #15 Situational Assessment.

The solution developed by the cadets at the USCGA had two main effects on the established disaster response system and particularly the Coast Guard. The first was an immediate operational effect during the response. The crisis maps developed by the cadets were a valuable information source used by Coast Guard pilots and command centers to coordinate rescues. The update rate was more frequent and the information more recent than the geospatial intelligence product. The second effect was a paradigm shift for a federal response agency. The Coast Guard is now considering how to formally integrate social media information in disaster responses rather than rely solely upon telephone-based calls for service.¹⁰⁶

The resilient communications network in the area affected by Hurricane Harvey created a unique disaster situation. With the communications network mostly intact, survivors were able to request assistance through any means available. The disaster environment conditions introduced the possibility of individual situation reports from the disaster area. This approach created real-time demands that needed to be addressed by a disaster response system. The massive information push to the established response system required the system to rethink methods and procedures. The same information push provided a large demand signal and associated opportunity for various disruptive emergent systems to begin operations to support survivors.

E. INSIGHTS AND ANALYSIS

The analysis of the four vignettes from the Hurricane Harvey response, the Cajun Navy, individual social media requests, virtual volunteers, and the USCGA, resulted in 108 codes. As in the previous analyses, the coded vignette data were condensed to create properties and features within each vignette that were carried over to the next coding analysis. This activity revealed seven properties and features of these emergent disruptive

¹⁰⁶ Ogrysko, "Recent Hurricanes Have the Coast Guard Rethinking Social Media's Role in Rescue and Response."

systems within the Hurricane Harvey response in Houston and the surrounding area. The initial and final set of the properties and features are shown in Table 4.

Table 4. Evolution of disruptive emergence properties and features through the Hurricane Harvey analysis.

Initial Vignette Features	Final Vignette Features
Humanitarian volunteerism	Humanitarian volunteerism / moral obligation
Community resilience (area, etc.)	Internal and external community resilience (physical and virtual)
Urgent / unmet needs	Urgent / unmet survivor needs
Operational requirements	Operational technology requirements and mindset
Organizational challenges	Ability to overcome organizational challenges Mission definition and perception Technological ability

The initial analysis revealed five properties and features of the first disruptive emergent system.

- *Humanitarian volunteerism* reflected codes that identified attitudes and motivations behind volunteer actions.
- *Community resilience* was a prevalent feature with direct ties to the first. This feature contains codes referring to assisting neighbors and external community-based assistance. The central Good Samaritan attitude drove resilience actions through the response.
- *Urgent / unmet needs* included codes that identified survivor needs and perceived gaps in the established response system.
- *Operational requirements* encompassed codes for activities related to communications, response assets, and equipment, including uses and needs.

- *Organizational challenges* incorporated all codes that addressed volunteer liability, safety, information tracking, and operational deconfliction.

Seven features emerged from the iterative analysis of the four disruptive emergent system vignettes. Using the constant comparative analysis method, features from the first iteration were updated to accommodate new aspects of the features revealed in the analysis of the additional disruptive emergent systems.

- The first feature became *humanitarian volunteerism and moral obligation* to encompass the range of attitudes surrounding volunteers within these disruptive emergent systems.
- *Internal and external community resilience (physical and virtual)* is closely related to the first feature. This feature was focused by codes denoting resilience-related centers and locations. In other words, existing physical communities in the affected area demonstrated resilience, while communities outside those areas formed to help survivors.
- The *urgent / unmet survivor needs* feature was modified to specify survivor needs as a motivating aspect of the disruptive emergent system.
- *Operational technology requirements and mindset* encompassed the codes that captured technology requirements for operations along with attitudes of volunteers who adopted new or repurposed technologies to accomplish a mission.
- *Ability to overcome organizational challenges* reflected agility and problem solving within the disruptive emergent system itself.
- A new feature that emerged during the analysis was *mission definition and perception*. This feature captured the codes representing actions, goals, and missions along with associated opinions about those actions, goals, and missions.

- *Technological ability* accounted for those codes that referenced the various technologies used to develop solutions through the disruptive emergent systems. These technologies were primarily digital tools that enabled communications, data gathering, and information displays. This feature also captured the challenges volunteers experienced with the technologies and data.

The features of the Hurricane Harvey disruptive emergent systems fall into similar categories identified during the Hurricane Sandy analysis: survivor demands, motivational factors, organizational mechanisms, and capabilities. The features *humanitarian volunteerism / moral obligation*, *urgent / unmet survivor needs* and *internal and external community resilience (physical and virtual)* combined to form the core motivational factors for the disruptive emergent systems. The features *humanitarian volunteerism / moral obligation* and *internal and external community resilience (physical and virtual)* fall into a culture subcategory on the supply side of the disruptive emergent system. The organizational mechanisms that enabled these disruptive emergent systems included *ability to overcome organizational challenges* and *mission definition and perception*. These two features provide the means for volunteers to act upon the motivational factors. The organizational mechanism category captures the shared purpose of volunteers within the disruptive emergent systems, the ability to adapt in an agile manner, and solve problems internal and external to the system. Finally, *operational technology requirements and mindset* and *technological ability* make up the capability category. This category includes the perceptual, organizational, and technical capabilities that helped these disruptive emergent systems operate within the extreme hurricane response environment. Elements within each disruptive emergent system perceived the requirements necessary to fill operational gaps, demonstrated the capability to self-correct challenges within each system to the benefit of survivors, and exhibited technological abilities for the good of the mission. Figure 4 shows the features visually organized in the ontological diagram structure used for the previous hurricane analyses.

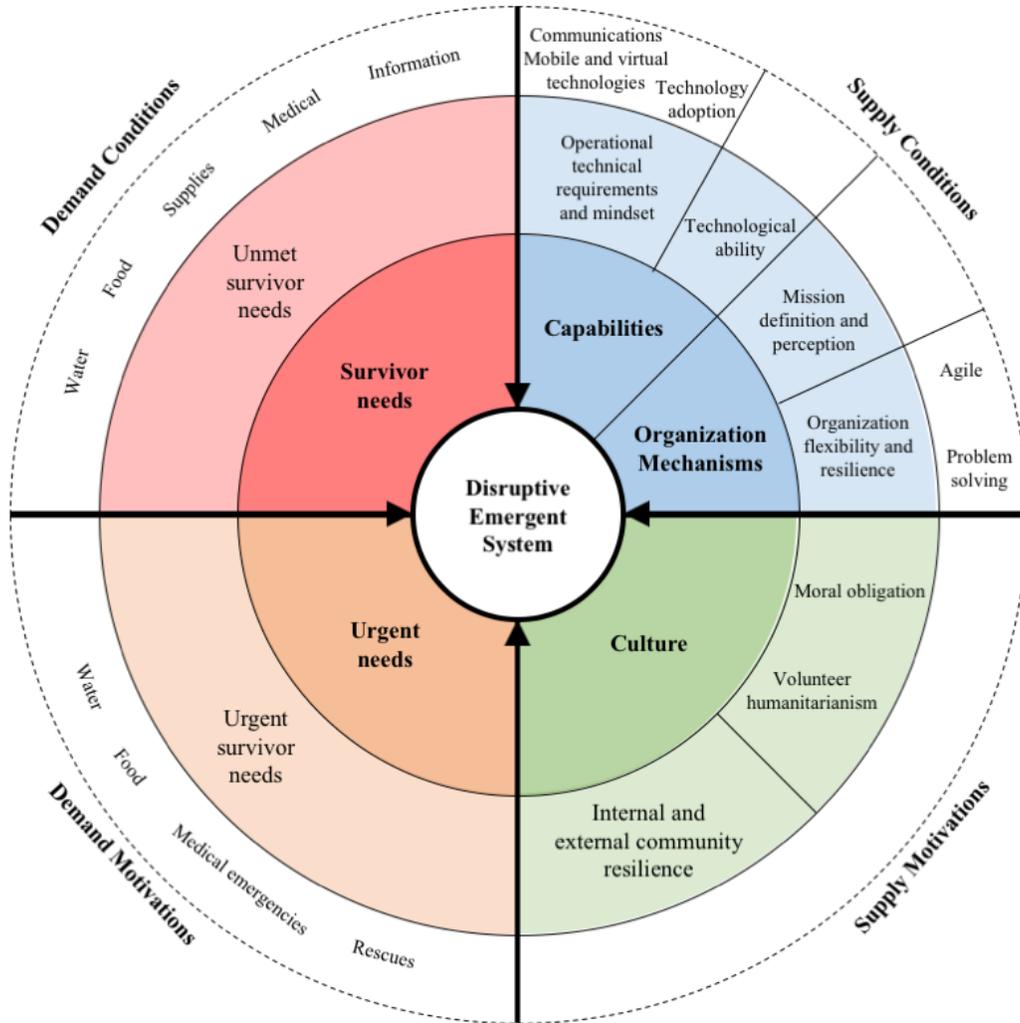


Figure 4. Disruptive emergent system ontological diagram for Hurricane Harvey vignettes.

The solutions generated through the disruptive emergent systems reviewed in this chapter supplemented or filled ESF #2 Communications, ESF #5 Information and Planning, and ESF #9 Search and Rescue. The core capabilities supported included #3 Operational Coordination, #4 Critical Transportation, #10 Mass Search and Rescue Operations, #12 Operational Communications, and #15 Situational Assessment. The ESFs and core capabilities fall within two categories: direct action to aid survivors and support efforts to assist the direct action. One disruptive emergent system, the Cajun Navy, conducted search and rescue operations in conjunction with critical transport as direct

action within the affected areas of Houston. The Cajun Navy also performed support activities, such as operational coordination, communication, and situational assessment driven by information generated through individual requests and virtual volunteers. As disruptive emergent systems, virtual volunteers and the USCGA team worked on similar problems as a support system, though sometimes not in coordination.

The capability features identified in this analysis enabled the Hurricane Harvey disruptive emergent systems to conduct direct actions and support functions to meet survivor needs. Capability features highlight how the disruptive emergent systems supplemented or filled gaps in the ESFs or core capabilities. The organizational mechanism features describe the processes used by disruptive emergent systems to deliver or modify capabilities. The underlying motivations and conditions drove both organizational mechanisms (e.g., resilience) and capabilities (e.g., technological solutions). These motivations and attitudes are essential for disruptive emergent systems that seek to support survivors in a disaster environment.

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VII. HURRICANE MARIA

Hurricane Maria struck the island of Puerto Rico on September 20, 2017, causing massive damage and flooding in many areas of the island, destroying structures, devastating the fragile electrical grid, and decimating the cellular network.¹⁰⁷ Electricity for the whole island was disabled. Entire communities were cut off when roads were washed out and destroyed by major flooding. Distribution of emergency supplies encountered physical and bureaucratic obstacles. Over 300,000 residences were damaged or destroyed.¹⁰⁸ Hospitals struggled to maintain emergency power for essential lifesaving and life sustaining equipment. Supermarkets also struggled to maintain emergency power for refrigeration units. The cumulative conditions on the island created many challenging circumstances and demands. These conditions provided opportunities for disruptive emergent systems to generate solutions and respond to survivor needs.

A. LOGISTICS FOR SUPPLIES

The island of Puerto Rico is approximately 1,200 miles away from Miami, Florida. Delivery of emergency supplies to the island is limited to ships and aircraft. Major ports and airports were inaccessible and closed in the immediate aftermath of the storm. After two days, the San Juan airport opened for military transport. Within the next four days, another seven airports and eight seaports reopened, some only for daylight operations.¹⁰⁹ Survivors who were able to contact relatives on the mainland reported that no aid supplies were being distributed and electricity alone was expected to take weeks if not months to restore. Families pooled resources to ship boxes of supplies on commercial flights from the

¹⁰⁷ Robinson Meyer, “What’s Happening With the Relief Effort in Puerto Rico?” *The Atlantic*, October 4, 2017, <https://www.theatlantic.com/science/archive/2017/10/what-happened-in-puerto-rico-a-timeline-of-hurricane-maria/541956/>.

¹⁰⁸ Jeff Goodell, “The Perfect Storm: How Climate Change and Wall Street Almost Killed Puerto Rico,” *Rolling Stone*, September 12, 2018, <https://www.rollingstone.com/politics/politics-features/puerto-rico-hurricane-maria-damage-722570/>.

¹⁰⁹ Meyer, “What’s Happening With the Relief Effort in Puerto Rico?”

mainland.¹¹⁰ Charitable organizations gathered donations and arranged transport from Florida on a cargo barge.¹¹¹ Mainland organizations teamed up with faith-based organizations on Puerto Rico to distribute supplies to those in need. A small group of doctors teamed up to gather medical supplies and solicit air transport from companies and private individuals.¹¹² With these relationships in place, this team of doctors were able to distribute 1,000 pounds of medical supplies to a hospital on Puerto Rico within five days of the hurricane's landfall.¹¹³

Three types of related disruptive emergent systems were observed in this vignette. The first was the coalescing actions of individuals to form ad hoc logistics networks to support communities on Puerto Rico. The second was a similar coalescing action of medical doctors to create new partnerships to deliver needed medical supplies to the island. The third was the creation of new partnerships between organizations to create a supply chain from scratch. Taken together, these logistics systems supplemented and, in some cases, filled federal ESF #6 Mass Care, Emergency Assistance, Temporary Housing and Human Services along with ESF #7 Logistics. The core capabilities supported by these disruptive emergent systems included #4 Critical Transportation, #9 Mass Care Services, and #13 Logistics and Supply Chain Management.

Obvious challenges exist for a disaster response over 1,000 miles away from major assistance networks.¹¹⁴ These challenges are compounded when transportation systems and infrastructure are damaged or destroyed. Disaster response efforts are not sequential, however. While the federal response system was restoring transportation capability to

¹¹⁰ Andrew Boryga, "The Agonizing, Undaunted Efforts to Bring Supplies to Loved Ones in Puerto Rico," *The New Yorker*, October 8, 2017, <https://www.newyorker.com/news-desk/the-agonizing-undaunted-efforts-to-bring-supplies-to-loved-ones-in-puerto-rico>.

¹¹¹ Vanessa Araiza, "I-4 for Puerto Rico Gets Creative Bringing Supplies to the Island," *WKMG*, September 26, 2017, <https://www.clickorlando.com/news/i-4-for-puerto-rico-gets-creative-bringing-supplies-to-the-island>.

¹¹² Amy Martyn, "Grass-Roots Network Of Doctors Delivers Supplies To Puerto Rico," *Kaiser Health News*, November 9, 2017, <https://khn.org/news/grass-roots-network-of-doctors-delivers-supplies-to-puerto-rico/>.

¹¹³ Martyn, "Grass-Roots Network Of Doctors Delivers Supplies To Puerto Rico."

¹¹⁴ Karl Vick, "A Land They No Longer Recognize," *TIME*, n.d., <http://time.com/a-land-they-no-longer-recognize/>.

Puerto Rico's sea and airports, the disruptive emergent systems were forming to develop logistics strategies to deliver supplies to the island. Transportation arrangements were made concurrently with donation collection. Organizers contacted connections on Puerto Rico, if possible, to smooth the supply distribution process. When airports and seaports were opened, the disruptive emergent systems were ready to deliver aid and supplies by the means available.

B. RADIO

The vast majority of communications networks had been knocked out by the hurricane. Nearly 95% of cellular towers were incapacitated and with the island's power grid completely disabled, limited options existed for survivors to get information. In these conditions, the people of Puerto Rico turned to one of the only sources of information left: AM radio. Residents found battery operated radio sets or used generators for electricity to power radios for information. Broadcasters at two AM radio stations remained on the air through the hurricane itself at great personal risk.¹¹⁵ Despite the roof being torn off one station, both continued to transmit thanks to strengthened antennas and generators.¹¹⁶ The stations endeavored to broadcast through the response, taking calls from survivors who still had working phone lines as well as friends and family on the mainland. These stations served as valuable information resources when no others were available. Besides providing information to the general public, these stations broadcast two calls to action that had direct influence on response operations at the request of Puerto Rican officials. The first was to the mayors of the 78 municipalities.¹¹⁷ Emergency management staff needed to coordinate with the mayors for supplies distribution but could only reach six by cellular phone. After the notice aired over the radio, 55 mayors arrived in San Juan the following day to coordinate efforts. The second was to the island's truck drivers.¹¹⁸ Emergency supplies

¹¹⁵ Bell, "After Hurricane Maria, AM Radio Makes a Comeback in Puerto Rico"; and Patricia Mazzei, "Maria Took a Puerto Rican Radio Station's Roof. But the Hosts Stayed on Air Anyway," *Miami Herald*, September 20, 2017, <https://www.miamiherald.com/news/weather/hurricane/article174409151.html>.

¹¹⁶ Mazzei, "Maria Took a Puerto Rican Radio Station's Roof. But the Hosts Stayed on Air Anyway."

¹¹⁷ Vick, "A Land They No Longer Recognize."

¹¹⁸ Vick, "A Land They No Longer Recognize."

were arriving on the island but not distributed due to lack of trucks. Many drivers were grappling with their own damaged homes or could not access fuel. After the radio call to action, the number of operating trucks doubled to 800 to distribute needed supplies throughout the island.¹¹⁹

The use of broadcast radio to transmit information for general and specific audiences is not a new or innovative concept, nor is broadcasting calls to action. However, this vignette centers on the resilience of the stations and willingness of broadcasters to stay on the air through the storm and after. The use of radio as the primary means of information was emergent due to the organic nature of its use. The use of AM radio represented a disruptive reverse in communications technology trends. This trend was verified a month later with radio advertising increased by 300 percent.¹²⁰ By broadcasting over AM radio as the main information source, broadcasters filled ESF #2 Communications, ESF #5 Information and Planning, and ESF #15 External Affairs. The core capabilities supported through these ESFs included #2 Public Information and Warning and #12 Operational Communications.

This vignette is unique within the selection studied in this research. The disruptive emergent solution, using AM radio broadcasts for information and calls to action, has existed for decades and was used exactly as designed. The disruptive emergent aspect of this solution stemmed from its assumed role in the response effort. Hardened infrastructure and personal resilience from broadcasters were essential for the stations to be broadcasting during and after the storm. Had the stations not strengthened their infrastructure or the broadcasters decided to leave, no other options for information would have existed for many survivors. The island's mayors would not have heard the call to assemble and organize supplies distribution. The island's truck drivers may have been much slower to return to truck driving. By filling the ESFs and core capabilities early in the response,

¹¹⁹ Vick, "A Land They No Longer Recognize."

¹²⁰ Bell, "After Hurricane Maria, AM Radio Makes a Comeback in Puerto Rico"; and Jim Wyss, "Without Power, Puerto Rico Turns to Radio for Information - and Company in the Dark," *Miami Herald*, October 17, 2017, <https://www.miamiherald.com/news/nation-world/world/americas/article179363811.html>.

broadcasters reinforced the relevancy of AM radio as an emergency communication mode made possible through personal and infrastructure resilience.

C. PROJECT LOON

Hurricane Maria completely disabled Puerto Rico's electrical grid along with roughly 85% of its cellular tower capacity.¹²¹ This situation left many survivors without a means to communicate, particularly from isolated areas in the interior of the island. To aid in the response effort and connect isolated communities, the company Alphabet deployed Project Loon to Puerto Rico. Project Loon employs geo-stabilized, high altitude balloons equipped with cellular transceivers to allow limited connectivity.¹²² Project Loon was designed for underserved areas to provide connections where none previously existed.¹²³ Alphabet quickly recognized the technology's usefulness in disaster areas to restore service. To deploy the balloons and operate the transceivers, Alphabet was quickly granted an experimental license by the U.S. Federal Communications Commission. Alphabet also rapidly developed partnerships with AT&T and T-Mobile to provide ground stations to complete the communications loop.¹²⁴ These partnerships normally take months to finalize but, in this case, Project Loon balloons were providing limited services to Puerto Ricans a month after the hurricane struck.

The emergence of these rapidly developed private partnerships and deployment of technology paved the way for Puerto Ricans in remote, isolated areas to access information and communicate. By assembling these technological partnerships, Project Loon filled the

¹²¹ Meyer, "What's Happening With the Relief Effort in Puerto Rico?"

¹²² Associated Press, "Google Parent Company Sends Up Solar-Powered Balloons to Bring Internet Service to Puerto Rico," *Los Angeles Times*, October 21, 2017, <http://www.latimes.com/business/technology/la-fi-tn-puerto-rico-balloons-20171021-story.html>.

¹²³ Nathan Mattise, "Project Loon Team Gave Puerto Rico Connectivity—and Assembled a Helicopter," *Ars Technica*, February 18, 2018, <https://arstechnica.com/science/2018/02/project-loon-engineer-sees-a-tool-for-future-disaster-response-in-puerto-rico/>.

¹²⁴ Mattise, "Project Loon Team Gave Puerto Rico Connectivity—and Assembled a Helicopter"; Larry Greenemeier, "Puerto Rico Looks to Alphabet's X Project Loon Balloons to Restore Cell Service," *Scientific American*, October 13, 2017, <https://www.scientificamerican.com/article/puerto-rico-looks-to-alphabets-x-project-loon-balloons-to-restore-cell-service/>; and David Lumb, "Project Loon Delivers Internet to 100,000 People in Puerto Rico," *Engadget*, November 9, 2017, <https://www.engadget.com/2017/11/09/project-loon-delivers-internet-100-000-people-puerto-rico/>.

response system's ESF #2 Communications along with core capabilities #8 Infrastructure Systems and #12 Operational Communications.

Project Loon was coordinated directly by Alphabet, a private sector company. Alphabet partnered with other companies to deliver a technological solution for the response effort. Formal government relationships were required with the FCC and the Puerto Rican government, but not through the federal response structure defined in the NRF. The partnerships and relationships Alphabet built in the short time between the hurricane and actually offering service were made outside the coordination efforts of the federal response effort. This solution presents positive and negative aspects for the federal response system. On the positive side, private sector companies can independently develop systems to assist response efforts. While intentions may be motivated by market share or profit, systems like this provide needed solutions during major response efforts. On the negative side, no coordination with the federal response system may increase the risk of redundant or conflicting efforts.

D. FEEDING PUERTO RICO

The massive electric outage led to many challenges on the island including shortage of cash to buy food and no power to cook. Chef José Andrés immediately recognized this need and flew to Puerto Rico to see what could be done.¹²⁵ Chef Andrés began cooking meals for survivors out of his friend's small restaurant kitchen with limited supplies and resources.¹²⁶ Demand for fresh, home-style cooked meals quickly grew. Within a week, Chef Andrés and a small team had cultivated a network of emergency kitchens and food trucks to serve over 50,000 meals.¹²⁷ The team initially focused on providing food for staff and patients at area hospitals, but demand continued to grow. Chef Andrés continued to

¹²⁵ José Andrés, "How a Team of Chefs Fed Puerto Rico after Hurricane Maria," TEDxMidAtlantic, video, 21:45, October, 2017, https://www.ted.com/talks/jose_andres_how_a_team_of_chefs_fed_puerto_rico_after_hurricane_maria.

¹²⁶ Daniella Cheslow, "Two Puerto Rican Chefs Weathered The Worst; Now Honored By The Best," *NPR*, March 13, 2018, <https://www.npr.org/sections/thesalt/2018/03/13/593211674/two-chefs-in-puerto-rico-up-for-james-beard-awards>.

¹²⁷ "#ChefsForPuertoRico," World Central Kitchen, accessed August 6, 2018, <https://www.worldcentralkitchen.org/category/puerto-rico>.

expand into Puerto Rico through more emergency kitchens and food trucks, tapping the resources of his nonprofit organization, World Central Kitchen (WCK), to pay for supplies and provide volunteer chefs through the WCK Chef Network. The WCK model in Puerto Rico was to use local resources and talent while providing survivors a means to volunteer and do good in the community. WCK focused on the positive psychological effects of home cooked food prepared in a familiar way to support survivors' physical and mental well-being.¹²⁸

Upon arriving in Puerto Rico, Chef Andrés laid the groundwork for an emergent system by focusing on leveraging local resources. As WCK led by Chef Andrés grew in capacity, the emergent system exhibited disruptive characteristics at increasing scale. By cooking and delivering meals, WCK supplemented and, in some cases, filled the federal response system's ESF #6: Mass Care, Emergency Assistance, Temporary Housing and Human Services and ESF #7: Logistics. These activities supported core capabilities #9 Mass Care Services and #13: Logistics and Supply Chain Management.

Through his efforts to feed Puerto Rico, Chef Andrés reached out to FEMA in San Juan but was ultimately rejected.¹²⁹ Despite this, Chef Andrés continued to build cooking capacity throughout Puerto Rico to provide meals for those survivors in need. Chef Andrés summarized the differences he saw between FEMA and the system he built in Puerto Rico:

The people of FEMA are great people. The men and women are smart, they are prepared, but they live under this amazing hierarchy pyramidal organizational chart that everybody falls out of their own weight. We need to be empowering people to be successful. What we did was a flatter organizational chart where everybody was owning the situation and we all made quick decisions to solve the problems on the spot.¹³⁰

The effect WCK had on the established response system in Puerto Rico can be characterized as a positive supplement. WCK operated as the federal response system expected an NGO to operate in a disaster environment. One key component of WCK's

¹²⁸ “#ChefsForPuertoRico”; and Andrés, “How a Team of Chefs Fed Puerto Rico after Hurricane Maria.”

¹²⁹ Andrés, “How a Team of Chefs Fed Puerto Rico after Hurricane Maria.”

¹³⁰ Andrés, “How a Team of Chefs Fed Puerto Rico after Hurricane Maria.”

disruptiveness is that WCK successes occurred despite a failed integration attempt with the federal response system.

E. ALTERNATIVE POWER

The widespread damage to the electrical grid on Puerto Rico was catastrophic, causing the entire island to lose power.¹³¹ The vast majority of residents did not have generators and many that did had trouble maintaining fuel supplies.¹³² Hospitals and supermarkets were also in dire need of fuel for generators to keep essential lifesaving and refrigeration equipment powered.¹³³ Officials estimated early that a minimum of six months would be needed to restore power to the whole island.¹³⁴ Residents and businesses quickly began to look for alternative sources of electricity. Tesla, the electric automaker, donated a large solar and battery storage electrical system to the San Juan Children's Hospital.¹³⁵ The systems provided all of the hospital's electricity needs and removed its reliance on the established electrical grid. Sonnen, a solar battery company, also donated battery systems to eight community clinics and kitchens to stabilize those services.¹³⁶ Non-

¹³¹ Meyer, "What's Happening With the Relief Effort in Puerto Rico?"

¹³² Samantha Schmidt and Joel Achenbach, "Hot, Isolated, and Running out of Supplies, Parts of Puerto Rico near Desperation," *Chicago Tribune*, September 24, 2017, <http://www.chicagotribune.com/news/nationworld/ct-puerto-rico-hurricane-maria-20170924-story.html>.

¹³³ Associated Press, "FEMA Ignored Puerto Rico in Aftermath of Hurricane Maria," *New York Post*, March 21, 2018, <https://nypost.com/2018/03/21/fema-ignored-puerto-rico-in-aftermath-of-hurricane-maria/>.

¹³⁴ Meyer, "What's Happening With the Relief Effort in Puerto Rico?"

¹³⁵ Bill Chappell, "Tesla Turns Power Back On At Children's Hospital In Puerto Rico," *NPR*, October 25, 2017, <https://www.npr.org/sections/thetwo-way/2017/10/25/560045944/tesla-turns-power-back-on-at-childrens-hospital-in-puerto-rico>.

¹³⁶ Daniella Cheslow, "Hurricanes Blew Away Puerto Rico's Power Grid. Now Solar Power Is Rising to Fill the Void," *Public Radio International*, January 4, 2018, <https://www.pri.org/stories/2018-01-04/hurricanes-blew-away-puerto-ricos-power-grid-now-solar-power-rising-fill-void>; and Danica Coto, "Tesla, Others Help Puerto Ricans Go Solar," *U.S. News & World Report*, July 26, 2018, <https://www.usnews.com/news/healthiest-communities/articles/2018-07-26/tesla-others-help-puerto-ricans-go-solar-amid-power-turmoil>.

profit groups and like-minded individuals quickly converged to create solar and battery solutions for remote areas of Puerto Rico.¹³⁷

The fragility of the electrical grid opened many opportunities for alternative electrical generation systems. The urgent needs of some, like hospitals, grocers, and people with life-sustaining equipment, drove rapid development and adoption of new systems. Most emergency generators, though widespread, were not designed for long-term use as a semi-permanent power solution.¹³⁸ These emergent solutions for electrical power stability supplemented the response system's ESF #12 Energy. This function supported core capabilities #8 Infrastructure Systems and #13 Logistics and Supply Chain Management.

The immediate effect of these alternative power solutions on the established system was a general movement away from the traditional approach to generating and distributing power. These alternative solutions reduced survivor needs in some areas for the established response system. By creating power solutions for hospitals and community centers, this disruptive emergent solution changed some of the demand signal for the established system. Survivors were able to meet basic power needs and move on to solving other problems while the established system continued to reestablish the electrical grid.

Overall, the disruptive emergent systems within the Hurricane Maria response concentrated on infrastructure elements. These elements included transportation, power distribution, communication, and food and supply distribution. Each of these systems were focused on survivor needs but needed to address infrastructure-related issues to meet those needs. Despite these wider challenges, disruptive emergent systems still formed to address the needs of survivors.

¹³⁷ Andres Viglucci, "They're Giving Puerto Ricans Power in a Dark Time. Solar Panels to the Rescue," *Miami Herald*, October 4, 2017, <https://www.miamiherald.com/news/weather/hurricane/article176821161.html>; and "Solar Libre: Family Affair," produced by Melanie La Rosa, 2017, in *How to Power a City: Stories from the Front Lines of the Clean Energy Revolution*, (Puerto Rico, 2018), <http://latinousa.org/2018/06/21/solarlibrefamilyaffair/>.

¹³⁸ Associated Press, "FEMA Ignored Puerto Rico in Aftermath of Hurricane Maria."

F. INSIGHTS AND ANALYSIS

The aggregation of the five vignettes from the Hurricane Maria response, logistics for supplies, radio, Project Loon, feeding Puerto Rico, and alternative power revealed 84 coded data points. Following the previous analyses, the coded vignette data were condensed to create properties and features within each vignette that were carried over to the next coding analysis. The condensing activity revealed eight properties and features of the emergent disruptive systems within the Hurricane Maria response. The evolution of the properties and features from the first vignette to the final is shown in Table 5.

Table 5. Evolution of disruptive emergence properties and features through the Hurricane Maria analysis.

Initial Vignette Features	Final Vignette Features
Transportation	Transportation methods & availability
Personal connections	Personal connections
Accepted routes and methods	Expanding accepted procedures and methods
Basic necessities	Meeting basic needs / necessities for survivors
Communications	Technical communications resilience and innovation
Community resilience	Community resilience and attitudes
	Technology and tech partnerships
	Creative operational partnerships

The initial analysis revealed six general features of the ‘logistics for supplies’ disruptive emergent system.

- *Transportation* encompassed transport methods to the island and on the island, along with transport challenges and successes.
- *Personal connections* captured those codes that recorded how personal connections were used to request, deliver, and distribute supplies to different areas on the island.
- *Accepted routes and methods* included the successes and failures of the established processes and procedures for emergency logistics.

- *Basic necessities* captured all codes related to survivor needs, such as clean water and food. Electricity was included in this feature insofar as it was needed to power lifesaving equipment.
- *Communications* included the communication methods and workarounds used to facilitate transport and distribution of emergency supplies.
- *Community resilience* encapsulated community-driven methods to collect and distribute supplies, including food and water.

The constant comparative approach resulted in eight features after analyzing the identified vignettes within the Hurricane Maria response.

- *Transportation methods and availability* represented the codes that addressed the use and availability of transportation modes to deliver supplies, food, water, and volunteers to various areas on the island.
- *Personal connections* expanded the original scope of codes to include motivations driven by personal connections.
- *Expanding accepted procedures and methods* incorporated how disruptive emergent systems adapted existing procedures and methods to meet system needs or requirements. In the Hurricane Maria response, this feature included many instances of repurposing operating equipment for specific missions.
- *Meeting basic needs / necessities for survivors* captured the overall goals for the disruptive emergent systems.
- *Technical communications resilience and innovation* incorporated codes that addressed the technological aspects of restoring and maintaining communications through innovative solutions. This feature was very prevalent during the response while responders attempted to overcome massive infrastructure failure, including communications networks.

- The sixth feature became *community resilience and attitudes* to better capture the attitudes that drove resilience within both internal and external communities.
- *Technology and tech partnerships* emerged as a feature through the constant comparative analysis. This feature included those codes that reflected the technology used to develop particular disruptive solutions and the organizational partnerships that made the solutions possible.
- *Creative operational partnerships* also emerged through the analysis. This feature encompassed the codes that identified partnerships that emerged to accomplish operational missions.

The disruptive emergent system features that were revealed through this analysis fell into four categories. As the previous analyses, these categories include demands, cultural factors, mechanisms, and capabilities. *Meeting basic needs / necessities for survivors* encompassed the survivor demands. Cultural factors include two features: *personal connections* and *community resilience and attitudes*. The perceived gaps in supplies along with personal friends and family connections drove strong motivations to overcome challenging obstacles. Community resilience and humanitarian attitudes served as cultural suppliers to the solutions and systems. Mechanisms address how the disruptive emergent systems began and operated. These mechanisms were created through the disruptive emergent system or were leveraged through existing mechanisms. In several cases, the mechanisms were enabled or created through partnerships. These partnerships fell within particular technology categories or various operational domains and supplied equipment, expertise, and volunteers. The capabilities of the disruptive emergent systems were directed by the motivational factors and enabled by the mechanisms. *Transportation methods and availability, expanding accepted procedures and methods, and technical communications resilience and innovation* combined to supply particular capabilities to meet specific needs. Figure 5 is the visual ontological representation of the disruptive emergent system features.

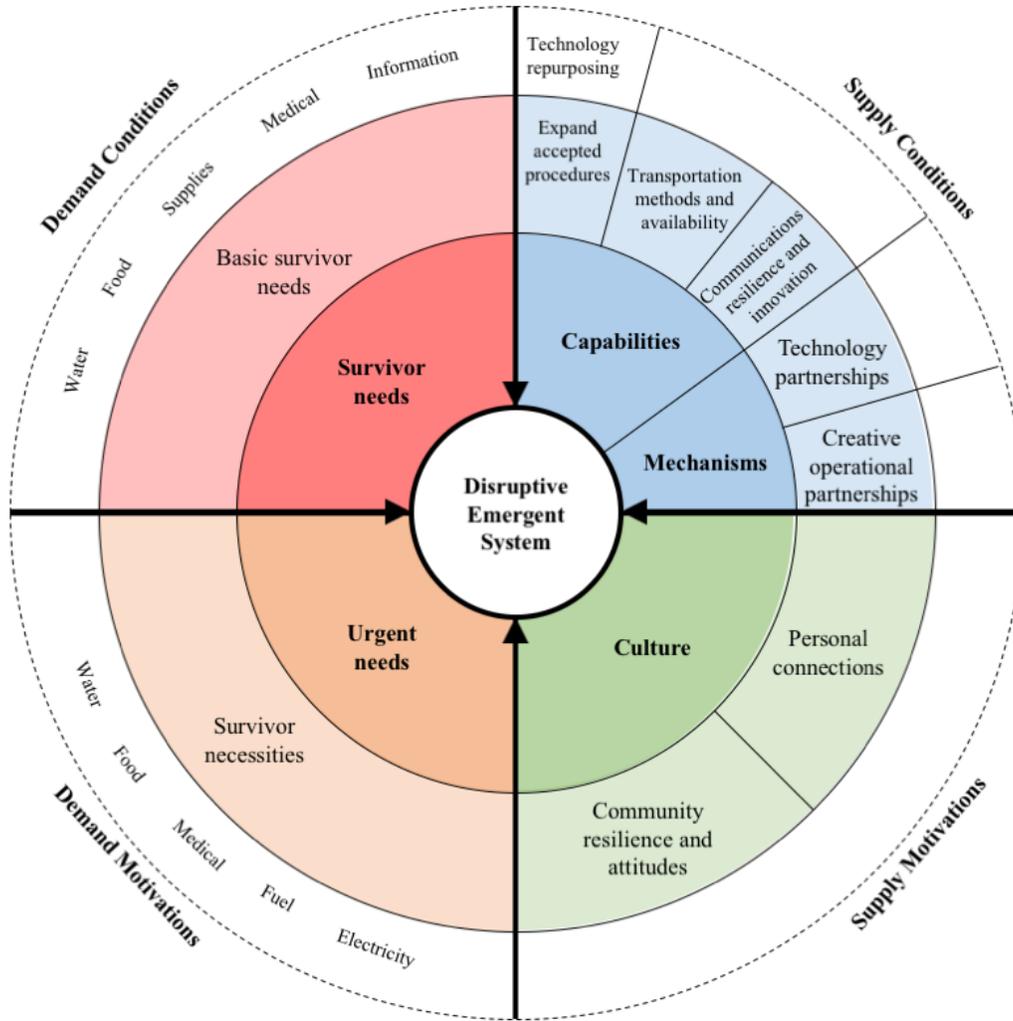


Figure 5. Disruptive emergent system ontological diagram for Hurricane Maria vignettes.

The disruptive emergent systems generated during the Hurricane Maria response supplemented or filled ESF #2 Communications, ESF #5 Information and Planning, ESF #6 Mass Care, Emergency Assistance, Temporary Housing and Human Services, ESF #7 Logistics, ESF #12 Energy, and ESF #15 External Affairs. The core capabilities supported by these disruptive emergent systems included #2 Public Information and Warning, #4 Critical Transportation, #8 Infrastructure Systems, #9 Mass Care Services, #12 Operational Communications, and #13 Logistics and Supply Chain Management. Through this response, the disruptive emergent systems addressed a wide range of response functions.

While the goals of the studied systems centered on delivering necessities or filling needs for survivors, other functions were sometimes needed to accomplish those goals.

The capability features were able to address some of the perceived gaps in the disaster response by supplementing or filling ESFs and core functions. Specifically, the disruptive emergent system features focused on restoring infrastructure-based services like communications networks, energy production, and transportation networks. Unique partnerships between government entities and private companies or NGOs emerged to provide mechanisms to enable these capabilities. In some cases, the perceived gaps in response were able to be addressed through personal connections. Supplies were transported and distributed to survivors in need based on communications through personal connections. These features collectively emphasized technology, creativity, and personal relationships to meet the needs of survivors on Puerto Rico.

VIII. ANALYSIS AND DISCUSSION

Chapters IV through VII reviewed vignettes of four hurricane responses. Each hurricane dataset was analyzed using the constant comparison method.¹³⁹ Within each hurricane response, vignette analyses built off the previous result. The analysis process resulted in properties and features of disruptive emergence for each particular hurricane response. Features reflect particular characteristics or attributes of the system. These properties and features were compared across each hurricane response. A total of 366 codes were identified across the 13 vignettes, of which 344 codes were unique. The primary analysis revealed a set of eight features of disruptive emergent systems in hurricane responses. The analysis and features formed the basis of an ontological diagram for disruptive emergent systems. The ontological diagram can be used to understand the conditions, motivations, supply, and demand that drive those systems. This chapter first describes the observed effects of disruptive emergent systems on the established response system. Then, it describes the constant comparative analysis across the hurricane features and analyzes the aggregated feature set. Finally, it discusses overall insights of and recommendations for disruptive emergent systems within hurricane responses.

A. EFFECTS OF DISRUPTIVE EMERGENT SYSTEMS

Disruptive emergent systems impact current disaster response systems in two distinct ways. The first affects the immediate response effort by directly engaging in operational aspects of ESFs and core capabilities. These disruptive emergent systems acted as force multipliers for the established response system by supplementing or filling gaps in operations. The second affects strategies within the established response system.

1. Operational Effects

Many of the disruptive solutions supplemented the established response system while the remainder filled gaps. The difference between supplemental activities and gap filling activities warrants a brief discussion. Actions of a disruptive emergent system that

¹³⁹ Glaser and Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*, 105.

operate alongside, in tandem with, or parallel to established system actions can be classified as supplemental. The actions of the disruptive emergent system expand the reach of an ESF that is being conducted by the established response system. Actions of a disruptive emergent system that fill gaps occur in locations or through an ESF that do not have established system coverage. In other words, the established response system representatives are not present in a geographic area or an ESF is not being addressed. The analysis revealed no evidence of a disruptive emergent system displacing any established responses.

The disruptive emergent systems in this analysis supplemented or filled eight of fourteen ESFs, as shown in Table 6. These eight ESFs have common threads in communication, information, and emergency aid. The remaining six are infrastructure related or require credentials and authority. For example, the Transportation and Public Works and Engineering ESFs require regulation, management, construction, or emergency repair of airports, roads, ports, and other infrastructure. These types of activities require specialized, expensive equipment and usually government authorization. Firefighting, Public Safety and Security, and Oil and Hazardous Materials Response activities generally require specialized training and authority granted through a government agency.

There are two ESFs that fall into the infrastructure or credentialed category but were still filled by disruptive emergent systems: Energy and Public Health and Medical Services. A disruptive emergent system was able to reduce the need for major energy infrastructure by introducing small scale solutions on individual or community levels. Instead of attempting to rebuild the entire energy grid in Puerto Rico, companies like Tesla provided solutions that did not require an island-wide electric grid. Other disruptive emergent systems were able to include medical practitioners in response efforts. Doctors, nurses, and other practitioners are credentialed but routinely volunteer in disaster environments. Firefighters, public safety officers, and hazardous material responders generally operate through established protocols and official requests to respond to a disaster outside of their area of responsibility.

Three ESFs that were supplemented or filled by disruptive emergent systems focused on communications and information. These domains have enjoyed major

advancements in technology since Hurricane Katrina that make mobile communication more accessible to more people. The final three ESFs, Search and Rescue, Logistics, and Mass Care, Emergency Assistance, Temporary Housing and Human Services are all oriented to provide needed services directly to survivors. The service-oriented aspect of these ESFs is very accessible to volunteers in direct or support capacities. The ESFs that each disruptive emergent system supplemented (S) or filled (F) are shown in Table 6. The columns in gray are ESFs that were not supplemented or filled by the disruptive emergent systems discovered in this research.

Table 6. Emergency Support Functions supplemented and filled by the disruptive emergent systems.

Disruptive Emergent Systems		Emergency Support Functions												
		Transportation	Communication	Public Works and Engineering	Firefighting	Information and Planning	Mass Care, Emergency Assistance, Temp Housing and Human Services	Logistics	Public Health and Medical Services	Search and Rescue	Oil and Hazardous Materials Response	Agriculture and Natural Resources	Energy	Public Safety and Security
Katrina	Cajun Navy & NOLA Homeboys					S			S					
	Common Ground Collective and Community Clinics							F						
Sandy	Occupy Sandy					F	F	F						F
	Social Technologies					S		S						S
Harvey	Cajun Navy					S			S					
	Individual Social Media Requests		S											
	Virtual Volunteers					S			S					
	USCGA					S			S					
Maria	Logistics for Supplies						F/S	F/S						
	Radio		F			F								F
	Project Loon		F											
	Feeding Puerto Rico						F/S	F/S						
	Alternative Power										S			

Many vignettes contained communications technology components or references. This is unsurprising since communication is a key component for coordinating disaster responses. However, technology that can be used for operational communications has become ubiquitous through mobile devices and internet technologies. Between 2005 and 2018, these technology advancements have reduced communication and information

barriers to entry for volunteers and allow many people the capability to contribute to ESFs. For example, prior to wide-spread, high speed internet use, virtual volunteer activities (e.g., crisis mapping) would not have been possible for many people. Now, people from all over the world can volunteer to support disasters in the United States due to advanced communications technologies.

In four vignettes, the disruptive emergent system supplemented or filled a single ESF. In these cases, the combination of perceived gaps and capabilities focused the purpose of the disruptive emergent system to a single ESF. In other cases, perceived gaps combined with capabilities to cross multiple ESFs in support of a single mission. For example, some disruptive emergent systems applied capabilities focused on information to support search and rescue missions. Within these disruptive emergent systems, an adaptive approach broke down silo-like ESFs to fill perceived gaps. In other words, some of these ESF-driven capabilities would be the responsibility of several different agencies across the established response system. This silo ESF structure requires extensive coordination. Disruptive emergent systems combined and adapted capabilities to meet demonstrated needs and targeted missions.

A disruptive emergent system that supplemented or filled an ESF did not necessarily support all of the core capabilities linked to that ESF. However, 11 of the 15 core capabilities were supported by the disruptive emergent systems examined in this analysis. Table 7 shows the core capabilities supported by each of the disruptive emergent systems. The core capabilities in gray were not directly supported by the disruptive emergent systems studied in this research.

Table 7. Core capabilities supported by the disruptive emergent systems.

Disruptive Emergent Systems		Core Capabilities														
		Planning	Public Information and Warning		Operational Coordination	Infrastructure Systems	Critical Transportation	Environmental Response / Health and Safety	Fatality Management Services	Fire Management and Suppression	Logistics and Supply Chain Management	Mass Care Services	Mass Search and Rescue Operations	On-scene Security, Protection, and Law Enforcement	Operational Communications	Public Health, Healthcare, and Emergency Medical Services
Katrina	Cajun Navy & NOLA Homeboys										X	X				
	Common Ground Collective and Community Clinics										X				X	
Sandy	Occupy Sandy	X	X	X						X	X					
	Social Technologies	X	X	X						X						
Harvey	Cajun Navy			X		X						X				X
	Individual Social Media Requests													X		
	Virtual Volunteers			X								X				X
	USCGA			X								X				X
Maria	Logistics for Supplies					X				X	X					
	Radio		X												X	
	Project Loon				X										X	
	Feeding Puerto Rico									X	X					
	Alternative Power				X					X						

Several disruptive emergent systems impacted trust in established disaster response system. During the Hurricane Katrina response, the NOLA Homeboys and Soul Patrol conducted many of the initial rescues in the Seventh Ward. The Common Ground Relief clinic served the needs of many people in the Algiers neighborhood. The perceived gaps in the federal response allowed these systems to emerge and meet survivor needs. With every person rescued or treated, these systems gained trust from survivors. Occupy Sandy experienced similar trust transitions. During the Hurricane Harvey response, the overloaded 9-1-1 system deteriorated trust in the response system to the point that survivors were openly broadcasting calls for help over social media. In the aftermath of Hurricane Maria, the mayor of San Juan publicly announced her distrust of the established system in a reaction to a positive characterization of the federal response efforts.¹⁴⁰ Distrust caused a variety of operational effects for the established response system. Survivors used the

¹⁴⁰ Meyer, “What’s Happening With the Relief Effort in Puerto Rico?”

resources available to them during the response to ensure their safety and survival. Survivor approaches that did not align with the established response revealed gaps in response coverage. In some instances, distrust arising through the response phase challenged the efforts of the established response system during the recovery phase. Distrust, whether deserved or the result of misaligned survivor expectations, should be taken seriously by the established response system and mitigated by leveraging trustworthy disruptive emergent systems.

2. Strategic Effects

Several disruptive emergent systems studied in this analysis had strategic effects on the established disaster response system. The Houston Police Department's decision to request assistance from boat operators, an indirect call for the Cajun Navy, is an example of a decision made by an established response system to leverage a disruptive emergent system. The Cajun Navy was propelled by its success in the Hurricane Katrina response. After being initially told to turn around during the Hurricane Katrina response, law enforcement officials indirectly requested the Cajun Navy during the Hurricane Harvey response.¹⁴¹ In the interceding twelve years, the established response system changed its view of the Cajun Navy's value in major urban flood environments. During the Hurricane Harvey response, the Houston Police Department made the strategic decision to leverage these force multipliers to save more lives.¹⁴²

Another example of a strategic impact involves the influx of requests for help sent through social media platforms during the Hurricane Harvey response. Social media updates sent during a disaster are not new and are the basis of crowdsourced crisis maps. Several VOADs have services based around this social media information. However, many of the updates sent during the Harvey response were specific requests for rescue, acting as substitutes for 9-1-1 calls for service. Many response organizations did not have a strategy

¹⁴¹ Koren, "Using Twitter to Save a Newborn From a Flood."

¹⁴² Koren, "Using Twitter to Save a Newborn From a Flood."

to receive, respond, and act on these social media requests. This situation caused response organizations to reevaluate social technology strategies.¹⁴³

The strategic decision to integrate a disruptive emergent system into the established response system is different than deciding to leverage that system. An integrated disruptive emergent system will coordinate and share information with the established system. When the disruptive emergent system is integrated, it becomes part of the established response. Coordination and information exchange will regularly occur between the response systems to provide the primary strategic benefit. **If the established response system would benefit from an information sharing paradigm with a disruptive emergent system, then integration should be pursued.** A clear example of integration with the established response system is the USCGA Digital Humanitarian Team. The team received feedback from field operators and modified their approach to information presentation in future deliveries. This iterative and integrated process ensured operators could maximize the disruptive emergent system ideas to meet survivor needs.

B. PROPERTIES, FEATURES, AND INSIGHTS

Each hurricane analysis resulted in a set of features and properties of disruptive emergent systems within that hurricane response. Each set formed the basis for an ontological diagram to describe the relationships and classifications of those features and properties. The resulting analyses are specific to the originating hurricane response. These data were used for a meta-analysis to determine common properties or features of disruptive emergence across the selected hurricane responses.

1. Meta-Analysis of Properties and Features

In keeping with the constant comparative approach, the feature sets were iteratively evaluated and aggregated. The core ideas, conditions, motivations, supplies, and demands were compared across the feature sets. In this meta-analysis, the colors displayed in each table align with the ontological diagram for each hurricane and identify the features in

¹⁴³ Ogrysko, "Recent Hurricanes Have the Coast Guard Rethinking Social Media's Role in Rescue and Response."

terms of conditions, motivations, supplies, and demands. Features that aligned across feature sets were generalized to the underlying common thread and reduced to one feature. Unique features were retained in the aggregated set. Hurricanes Katrina and Sandy were compared and aggregated to develop a general feature set for both. Table 8 contains the color-coded and aligned feature sets from Hurricanes Katrina and Sandy.

Table 8. Color-coded alignment of Katrina and Sandy features.

Katrina Features	Sandy Features
Response time drove decision making	Urgent survivor needs
Unmet survivor needs / basic necessities	Unmet survivor needs
Community resilience attitude - solidarity	Supportive external community resilience
	Volunteer humanitarianism
Insufficiency of accepted methods and procedures	Use of accepted routes / methods / procedures
	Creative problem solving
	Capability to leverage technology
Agile, decentralized services	Rapid response time / useful actions
	Grassroots organizing abilities

Several common threads appeared through this meta-analysis.

- *Response time drove decision making* correlated to *urgent survivor needs*. This combination used *response time* and *urgency* as the common links to develop an aggregated feature. This new feature, *rapid response time for*

urgent survivor needs, included the underlying decision making required to create a disruptive emergent system able to respond to urgent survivor needs.

- *Unmet survivor needs / basic necessities* feature linked to *unmet survivor needs*. The commonality between these features is self-evident. The feature from the Hurricane Sandy analysis was split between *urgent* and *unmet needs* to focus clearly on the conditions and motivations within the needs.
- *Community resilience attitude - solidarity* and *supportive external community resilience* were joined by the community resilience thread. The resultant meta-feature was *local and external community resilience and solidarity*.
- *Insufficiency of accepted methods and procedures* connected with *use of accepted routes / methods / procedures*. While accepted methods is common to both features, insufficiency related more to unmet needs. A main idea underlying the accepted methods thread was the creative use of those methods or that the methods are leveraged by disruptive emergent systems. These accepted methods features were combined with creative problem solving and capability to leverage technology and methods.
- *Agile, decentralized services* encompassed *rapid response time / useful actions* through a common rapid flexibility component. Rapid response and useful actions were viewed as components of agile and decentralized services.

Volunteer humanitarianism and *grassroots organizing abilities* did not have corresponding links to the other feature set and were integrated into the aggregated feature set. Table 9 lists the aggregated, color-coded feature set.

Table 9. Color-coded aggregated features of Hurricanes Katrina and Sandy.

First Aggregation (Katrina and Sandy)
Rapid response time for urgent survivor needs
Unmet survivor needs
Local and external community resilience and solidarity
Volunteer humanitarianism
Agile, decentralized services
Grassroots organizing abilities
Creative problem solving
Capability to leverage technology and methods

Next, the aggregated feature set was compared to the Hurricane Harvey feature set using the same comparison method.

- *Rapid response time for urgent survivor needs* encompassed urgent survivor needs, as in the first aggregation.
- *Unmet survivor needs* were present in each list. As in the first iteration, the corresponding Hurricane Harvey feature was split between *unmet needs* and *urgent needs* to isolate the differences between the two concepts.
- *Local and external community resilience and solidarity* connected with *internal and external community resilience (physical and virtual)* through a common resiliency core. The resultant meta-feature was *local and external community resilience and solidarity through physical and virtual actions* to include all components from each.

- *Volunteer humanitarianism* correlated to *humanitarian volunteerism / moral obligation*. These two features captured the same ideas, though the Harvey feature expanded into moral obligation. In this case, the wording from the Harvey feature was retained to encompass all components of the features.
- *Agile, decentralized services* coupled with *mission definition and perception*. These two features described the two sides of accomplishing a mission: what mission and how the mission should be accomplished. The resultant meta-feature captured both sides: *agile, decentralized operations for a defined and accepted mission*.
- *Grassroots organizing abilities* connected with *ability to overcome organizational challenges* through the underlying idea of organizational capabilities. The resulting meta-feature was *grassroots organizational flexibility and resilience*, to include general organizing abilities.
- *Capability to leverage technology and methods* linked with two features within the Harvey set: *operational technology requirements and mindset* and *technological ability*. Technology, capabilities, and operations supported each of these features. The resulting meta-feature was *capability and willingness to leverage technology for operations*.

One feature, *creative problem solving*, was unlinked and was integrated into the second iteration of the meta-feature set. Table 10 shows the color-coded and aligned features for both the first aggregation and Hurricane Harvey. Table 11 contains the aggregated features from Hurricanes Katrina, Sandy and Harvey as a color-coded list.

Table 10. Color-coded alignment of the first aggregated feature list with Hurricane Harvey features.

First Aggregation (Katrina and Sandy)	Harvey
Rapid response time for urgent survivor needs	Urgent survivor needs
Unmet survivor needs	Unmet survivor needs
Local and external community resilience and solidarity	Internal and external community resilience (physical and virtual)
Volunteer humanitarianism	Humanitarian volunteerism / moral obligation
Agile, decentralized services	Mission definition and perception
Grassroots organizing abilities	Ability to overcome organizational challenges
Creative problem solving	
Capability to leverage technology and methods	Operational technology requirements and mindset
	Technological ability

Table 11. Color-coded aggregated features from Hurricanes Katrina, Sandy, and Harvey.

Second Aggregation (Katrina, Sandy and Harvey)
Rapid response time for urgent survivor needs
Unmet survivor needs
Local and external community resilience and solidarity through physical and virtual actions
Humanitarian volunteerism / moral obligation
Agile, decentralized operations for a defined and accepted mission
Grassroots organizational flexibility and resilience
Creative problem solving
Capability and willingness to leverage technology for operations

Finally, the feature set from the Hurricane Maria analysis was compared with the second meta-feature set using the same analysis method.

- *Rapid response time for urgent survivor needs* encompassed *necessities for survivors*. As in the previous iterations, the Hurricane Maria feature was split to capture the separate but related ideas.
- *Unmet survivor needs* correlated with *meeting basic needs*. The Maria feature included information along with a long response phase. The modified meta-feature, *reduce gaps in response*, accommodated this shift while including all aspects of the original meta-feature.
- *Local and external community resilience and solidarity through physical and virtual actions* coupled with *personal connections and community resilience and attitudes*. Personal connections were a subset of

community, local or external. In this case, the meta-feature already encompassed the two Maria features and remained the same.

- *Agile, decentralized operations for a defined and accepted mission* linked with *transportation methods and availability*. The unconventional and decentralized aspects of the Maria feature formed the basis for this link. Transportation was grouped into operations to support an accepted mission. For this link, the meta-feature was not modified.
- *Creative problem solving* connected to *technical communications resilience and innovation* and *creative operational partnerships*. Creativity, innovation, and problem solving were key components of each of these features. The resultant meta-feature was *creative problem solving through operational partnerships and innovative technological solutions*.
- *Capability and willingness to leverage technology for operations* merged with *technology and tech partnerships* and *expanding accepted procedures and methods*. This aggregation captured the leveraged combination of technology and partnerships to grow current methods into additional response areas. The aggregation resulted in *capability and willingness to leverage technology and partnerships for operations*.

Humanitarian volunteerism and moral obligation and *grassroots organizational flexibility and resilience* did not correlate with any Maria features and were retained in the final meta-feature set. Table 12 shows the second color-coded meta-feature set aligned with the Hurricane Maria set. Table 13 contains the final meta-feature set which aggregated features from each of the four hurricane responses. This final meta-feature set represents a disruptive emergent system ecology, which describes when and how disruptive emergent systems may occur.

Table 12. Color-coded alignment of the second aggregated feature list with Hurricane Maria features.

Second Aggregation (Katrina, Sandy and Harvey)	Maria
Rapid response time for urgent survivor needs	Necessities for survivors
Unmet survivor needs	Meeting basic needs
Local and external community resilience and solidarity through physical and virtual actions	Personal connections
	Community resilience and attitudes
Humanitarian volunteerism / moral obligation	
Agile, decentralized operations for a defined and accepted mission	Transportation methods & availability
Grassroots organizational flexibility and resilience	
Creative problem solving	Technical communications resilience and innovation
	Creative operational partnerships
Capability and willingness to leverage technology for operations	Technology and tech partnerships
	Expanding accepted procedures and methods

Table 13. Final aggregation of disruptive emergent system features in hurricane responses.

Final Aggregation
Rapid response time for urgent survivor needs
Reduce gaps in response
Local and external community resilience and solidarity through physical and virtual actions
Humanitarian volunteerism / moral obligation
Agile, decentralized operations for a defined and accepted mission
Grassroots organizational flexibility and resilience
Creative problem solving through operational partnerships and innovative technological solutions
Capability and willingness to leverage technology and partnerships for operations

The feature meta-analysis revealed three observations. First, unmet needs and perceived gaps are common demand signals for all disruptive emergent systems. Each disruptive emergent system sought to fill a perceived gap in the established system response. This common demand signal is expected. Without a demand of some form, a disruptive emergent system would not emerge. That is, in the case of hurricane responses, established response systems exist to satisfy survivor demands while disruptive emergent systems are generated to supplement or fill gaps in the established system supply. Each of the disruptive emergent systems examined in this research evolved in response to at least one survivor need. A response system could be generated that creates additional demand through a form of producer-user interaction, but this type of system would not be classified as a disruptive emergent system within the context of this research.

Second, some form of community resilience or resilience support is a common cultural input for all disruptive emergent systems. A resilient culture may be applied to all manner of communities. Communities within the affected area, outside the affected area,

virtual groups, NGOs, or private businesses may all contribute to a resilient culture for a particular response.

Finally, not all types of features were prevalent in each of the disruptive emergent systems. This phenomenon may have occurred for two methodological reasons. The first is that the constant comparative approach continually iterates levels of abstraction. In other words, it is possible that features were masked or lost through the abstraction process. The second reason may reflect inconsistencies through the coding process. Codes may not have been captured or organized into features the same way between hurricane responses. However, this analysis approach examined each hurricane independently. If a sequential analysis approach was used to build features across all vignettes regardless of hurricane, a similar feature set would be expected. Slight variances in the results could be anticipated if the analysis was completed in a different order.

2. Insights from Properties and Features

The aggregated features reveal several insights about disruptive emergent systems and the ecology of those systems. First, disruptive emergent systems seek to resolve particular demands on the overall response environment. The disruptive systems that emerged in these hurricane responses needed at least one survivor demand signal. The systems endeavored to supply solutions to meet that demand signal. Without the demand signals, supplied solutions, and underlying features, disruptive emergent systems likely would not emerge. Second, this analysis showed that particular conditions within the disaster environment are conducive for disruptive emergent systems. Specifically, demand must exist, and a supply source to meet those demands must be feasible within the disaster environment. Finally, motivations to satisfy demands must be present to support disruptive emergent systems. Motivations include cultural components and timeliness requirements.

The features that reflect demands are *reduce gaps in response* and *rapid response time for urgent survivor needs*. The former feature represents identified needs or perceived gaps that exist as conditions of the disaster environment. For example, survivors may need clean water because the disaster disabled the water distribution system. The latter feature addresses the urgency of particular needs in terms of motivation. *Rapid response time for*

urgent survivor needs is a motivational factor, rather than a demand for motivation. For example, power for medical devices is a time-sensitive need. This situation serves as a motivational pull for an energy-related disruptive emergent system. These features reside on the demand side of the disruptive emergent system ecology but are framed as properties of those systems in terms of overall ability to meet demands. In other words, these features represent the general ability of the system to provide solutions for the demand signals.

Features that supply solutions to meet demands fall into capabilities, mechanisms, and culture. The features that represent capabilities are *creative problem solving through operational partnerships and innovative technological solutions* and *capability and willingness to leverage technology and partnerships for operations*. These features capture the general products of disruptive emergent systems. These products, in the form of solutions, partnerships, or technologies, are developed to meet the demands of survivors. Capabilities for disruptive emergent systems are developed and refined to meet specific needs and help define the operations conducted by the system. Capabilities may be similar to or the same as capabilities within the established response system or could be radically different. However, the capabilities will be developed as the disruptive emergent system evolves to address survivor needs.

The features that represent mechanisms are the *grassroots organizational flexibility and resilience* and *agile, decentralized operations for a defined and accepted mission*. These features collectively describe organizational mechanisms that enable disruptive emergent systems to provide solutions to survivors. These systems need to be resilient themselves to overcome inevitable challenges within inherently chaotic disaster environments. Adapting to organizational challenges can be difficult while coping with environmental challenges but is necessary to deliver solutions. A defined mission is necessary for the disruptive emergent system to develop solutions that meet survivor needs. This mission definition is essential for decentralized and agile operations, which are common hallmarks of disruptive emergent systems. Without an accepted mission definition, the decentralized structure of the system may break down or cause organizational splintering.

Finally, the features that represent culture are *local and external community resilience and solidarity through physical and virtual actions* and *humanitarian volunteerism and moral obligation*. These culture features serve as motivators for the disruptive emergent systems. In this regard, culture features are the foundation and impetus for many systems and solutions. Community resilience and solidarity can take many forms in many different locations. Community resilience need not be restricted to the community affected by a disaster. Communities outside the disaster area can travel to the affected zone or provide support virtually. Virtual communities within actual communities have the ability to reinforce resilience and solidarity through rapid information dissemination. Individuals may be motivated to volunteer by humanitarian or moral ideals. These ideals spur volunteers to provide their time and expertise to develop or implement solutions for survivors.

The overall ontological diagram (Figure 6) follows the same general structure as the individual hurricane diagrams. However, the Supply Conditions and Supply Motivations quadrants break down several features in more detail in the outermost ring and flow to more general features, indicated by arrows. For example, the operational partnerships component within the Supply Conditions quadrant is unique because it is part of two separate features. In one feature, operational partnerships are used for creative problem solving while in the other, they are leveraged for actual operations. This is illustrated by Occupy Sandy's use of Amazon's wedding registry to creatively solve a donation logistics problem and provide useful recommendations for would-be donors. While not an official partnership between Occupy Sandy and Amazon, the creative system the two formed resulted in an additional donation capability. During the Hurricane Harvey response, the Cajun Navy partnered with the Houston Harvey Rescue database to collect data and provide operational information. The two formed an operational system that leveraged the operational strengths of each to rescue thousands.

Disruptive Emergent System Ontological Diagram

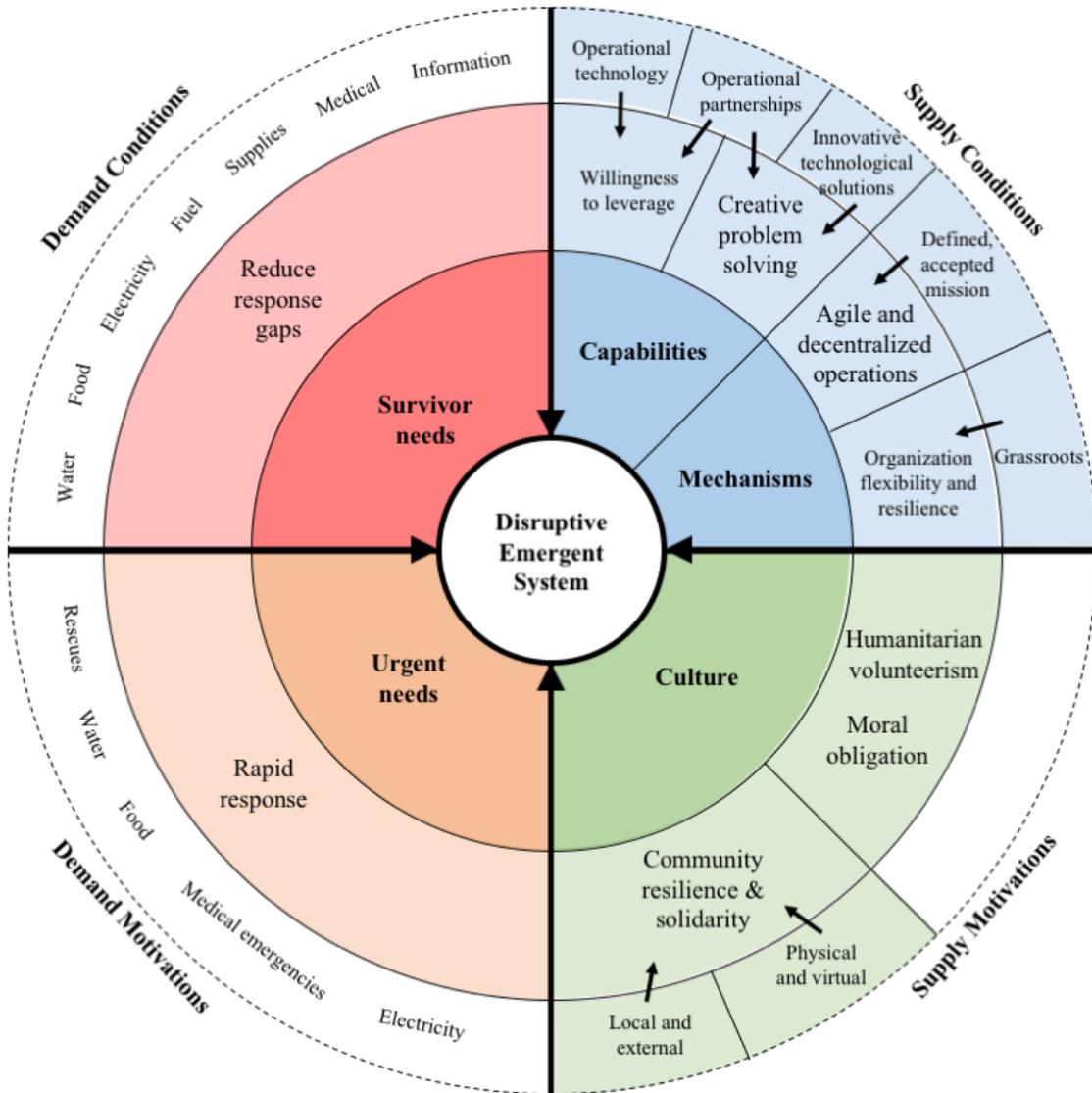


Figure 6. Overall ontological diagram for disruptive emergent systems in hurricane responses.

The ontological diagram for disruptive emergent systems visualizes the general features that make up those systems. System features form around survivor-centric services and demands. The demand and supply diagram components reflect the need for systems to fill perceived gaps in the response effort. The conditions and motivations paradigm highlight the intrinsic components required for the systems to function. Survivor centrality is reflected in each of the features.

C. THE FUTURE OF DISASTER RESPONSE SYSTEMS

Disaster response systems will continue to modify processes and adapt to new technologies and conditions. This evolution is evident within each disaster, through technology advancements, and through changing perceptions of those systems. These elements, along with potential leverage points and recommendations, will be reviewed in this section.

1. Evolution of Disruptive Emergent Systems

Disruptive emergent systems are not static entities. Each system examined in this research exhibited a form of evolution from its initial state. All of the systems started with basic features and adjusted as necessary to meet survivor needs. For example, the Cajun Navy operated boats until rescues were no longer necessary. Then they went home. Occupy Sandy adjusted mission focus from collecting and distributing donations during the initial response to pumping out and gutting houses to prepare for recovery operations. Tesla used the San Juan Children's Hospital as a solar energy pilot program and expanded installations from there. Each of the disruptive emergent systems either dissolved or moved on after completing the mission, transitioned into different recovery missions, or became sustained solutions within the community. This evolution is based on changing survivor needs throughout the disaster response.

Technology evolution has also driven change in disruptive emergent systems. For example, between 2005 and 2017, smartphone and mobile technologies experienced many advances. These advancements set the stage for new capabilities and mechanisms to support survivor needs. For instance, the Cajun Navy executed the same mission for Hurricanes Katrina and Harvey, with one notable exception. During the Hurricane Harvey response, the Cajun Navy relied upon mobile technologies for navigation, dispatch, and tracking rescue cases. These technologies allowed rescues to be directed and managed from Louisiana while increasing the available pool of volunteers. The Cajun Navy's primary mission did not change from Hurricane Katrina to Hurricane Harvey. Nor did the central motivations or survivor demands. The principal change was the communication and social tools available. These tools allowed the Cajun Navy to modify the organizational

capabilities and mechanisms to meet survivor needs. The Cajun Navy is the only longitudinal example of a disruptive emergent system discovered through this research. Therefore, this system serves as an illustrative example of the influences technology may have on a disruptive emergent system in terms of capabilities and mechanisms.

The natural evolution of disruptive emergent systems over the course of a response and potential technologically-driven change are two forms of evolution these systems encounter. The perception of the system from the public or established response system may also evolve. The perception of legitimacy for disruptive emergent systems has changed through the evolutionary processes during or across responses. This change is evident in several vignettes:

- The established response system legitimized the Cajun Navy by requesting assistance of boaters during the Hurricane Harvey response.¹⁴⁴ This occurred 12 years after the initial call went out requesting assistance from boaters, only to be told to go home by law enforcement during the Hurricane Katrina response.
- Residents in the Algiers neighborhood of New Orleans viewed the Common Ground Relief clinic as the legitimate response to Hurricane Katrina challenges. The clinic is still operating.¹⁴⁵
- After initially being brushed aside by the established system, Occupy Sandy volunteers served as community experts for established response organizations and received supplies to distribute from established NGOs.¹⁴⁶ The legitimizing actions took days and weeks to occur.

¹⁴⁴ Koren, “Using Twitter to Save a Newborn From a Flood”; and Nelson, “In Houston, Pleas for Help Go out over Social Media: ‘Please Send Help. 911 Is Not Responding.’”

¹⁴⁵ Shorrock, “Common Ground”; and “Common Ground Health Clinic - Home.”

¹⁴⁶ Feuer, “Where FEMA Fell Short, Occupy Sandy Was There”; and Kilkenny, “Occupy Sandy Efforts Highlight Need for Solidarity, Not Charity.”

- The operational Coast Guard legitimized the efforts of cadets by requesting updated crisis response maps.¹⁴⁷ This solution was adopted almost immediately during the Hurricane Harvey response phase.

These disruptive emergent systems were legitimized at widely varying rates. For the Cajun Navy, a form of legitimization occurred 12 years after the initial system emerged. For the USCGA cadets, legitimization was nearly immediate. A major factor in legitimizing disruptive emergent systems is risk. Boaters of the first-generation Cajun Navy were turned away from the floodwaters because law enforcement officials did not want to risk the possibility of additional people needing rescue. However, for the recent generation Cajun Navy, the benefits of force multipliers to rescue operations outweighed the assumed risk for law enforcement officials. Virtual solutions, like crisis maps or informational websites, carry less risk into the actual disaster area than volunteers. These solutions may introduce other risks to the disaster response but have been tacitly accepted during recent operations. Recognition of legitimacy for disruptive emergent systems by the established response system tends to occur after demonstrated success in meeting survivor needs.

Given the evolutionary characteristics of the disruptive emergent systems, the perception of those systems, and the available technology, many different outcomes could be realized in future disaster response systems. In a futurist's world, swarming drones could be sent into disaster areas to generate crisis response maps. Small drones, controlled by remote volunteers, could deliver urgent medication or communications devices to those in need. Autonomous shallow water boats could be automatically dispatched to rescue survivors. However, future systems and capabilities evolve, survivors will always have needs in disaster responses and people will be motivated to meet those needs. This research provided a small snapshot of those consistent features across hurricane responses. These consistencies provide many opportunities for social entrepreneurs seeking to make positive impacts on society, thereby encouraging the creation of disruptive emergent systems.

¹⁴⁷ McIntyre, "Keene High Grad in Coast Guard Academy Helps Hurricane Harvey Response Efforts"; and Twarog, "Searching for the Pulse of Technology."

2. Disaster Response Systems Should Leverage Disruptive Emergent Systems

Overall, each of the disruptive emergent systems satisfied some survivor needs and provided benefit to the communities in which they operated. This research has reinforced that disruptive emergent systems provide benefit to survivors while supplementing or filling gaps in the established response. The established disaster response system should seek to leverage those systems as force multipliers or gap fillers. How can disruptive emergent systems be identified early so they can be leveraged?

Potential disruptive emergent systems could be identified based on the overall features within the ontological diagram. When demands are not being met through the established response system via ESFs or core capabilities, a disruptive emergent system may arise to fill those gaps. Survivor demands that are not met are divided in the ontological diagram by conditions and motivations. A thorough understanding of the disaster environment profile is important to identify conditional demands that may drive other elements of the ontological diagram. For example, infrastructure conditions within the disaster environment will directly impact survivor needs. Electricity and clean water distribution along with roadway and communications networks are all infrastructure components that impact survivor demands. After Hurricanes Katrina and Maria, much of this infrastructure was inoperable within the affected areas. The effect of Sandy on infrastructure depended upon the location within the affected area. Hurricane Harvey disabled much of the electricity and water distribution while flooding many roadways. However, the cellular communications network was left largely intact, which provided opportunity for disruptive emergent systems through the disaster environment profile. In each of these hurricane response environments, many specific survivor needs can be expected based on the disaster environment profile.

Motivation-based demands also have an influence on certain supply features. For example, demands for rescues will promote rescue capabilities on the supply side of the ontological diagram. Certain timely demands will always exist in disaster environments that will promote particular capabilities in power generation, medical response, and lifesaving. These motivations are also based on the disaster environment profile,

particularly concerning infrastructure status. A failure in electricity distribution will cause immediate consumption of fuel reserves for emergency generators. The demand for fuel will continue to increase as reserves are used due to the need for electricity to keep critical equipment running. This is particularly important for lifesaving equipment within hospitals. Anti-flooding infrastructure is another example of a failure that will present motivation-based demands. In this case, survivors need to be rescued from floodwaters in a timely manner. Taken together, conditional and motivational demands can be observed based on the disaster environment profile, starting with infrastructure within the affected area.

Capabilities, on the supply side of the diagram, represent technologies and overall strategies that systems may use to accomplish a mission. For example, mobile and social technologies played significant roles in several of the reviewed disruptive emergent systems. In some cases, these capabilities facilitated survivor rescues, from information collection and dissemination to navigation and record keeping. In other cases, these capabilities enabled volunteer mobilization and dispersed organization. Equipment capabilities combined with partnerships formed supplementary solutions. Shallow water boats navigated by operators with mobile tools managed by remote volunteers, food trucks used to distribute fresh meals through an extensive volunteer food aid network, and private companies voluntarily installing new technology to restore power for community services are all examples of leveraged partnerships.

Creative problem solving is an important component of capability for disruptive emergent systems. Several systems accomplished missions by adopting technologies not typically used in a disaster response context in the United States. For example, the widespread use of social media by survivors during the Hurricane Harvey response had not been seen to that extent before. This use of technology was a creative solution to the larger communications problem within the response system. Mobile applications were adopted during both Harvey and Sandy responses in ways that were new to disaster response. In a disaster environment, overall capabilities of a disruptive emergent system can be observed by the established system if both systems are operating within the same region of the disaster area. Observation is also possible through news media. Volunteer narratives are

less centralized than NIMS-based media communications and may be more accessible. Capabilities can be discovered through media reviews, much like the process for this research.

Mechanisms, also on the supply side of the diagram, may be difficult to observe or identify with a top-down approach. Agile and decentralized systems may appear to be a set of small, separate systems conducting similar missions. Grassroots-type systems may not have a main point of contact for other organizations to liaise with or any type of hierarchy. However, the mechanisms of a disruptive emergent system may be readily identified through a bottom-up approach by leveraging contact at the lowest level of operations. On the other hand, mechanisms for private-public partnerships can be prepared in advance. Fast-track approval processes for disaster response and relief technologies could be part of a pre-staging strategy for the established response system.

Culture can also be difficult to detect. However, certain aspects of culture persisted throughout many of the vignettes studied in this research. Humanitarian volunteerism and community resilience were enduring features throughout the disruptive emergent systems. Some level of humanitarian or resilience culture may naturally exist in any type of disaster response. This culture is reinforced by VOADs that operate within the physical disaster area or virtually. While recognized VOADs may not be part of a disruptive emergent system, the cultural behaviors of VOADs may be mirrored by an emerging disruptive system.

The purpose of identifying a disruptive emergent system within a disaster response is to recognize the benefits of the system for survivors and determine how the system may be leveraged by the established response system. Several examples of leveraged systems were studied in this research, including Occupy Sandy, the USCGA Digital Humanitarian Team, and the Cajun Navy. Volunteers within the Occupy Sandy movement served as community needs subject matter experts and liaisons for the established response system, including VOADs. The established system did not initially recognize Occupy Sandy as a force to be leveraged, but the success of Occupy Sandy served to shift that sentiment. The established response system leveraged Occupy Sandy aspects that were concentrated mostly on community knowledge and supplies distribution.

The USCGA Digital Humanitarian Team solution was leveraged by the ongoing response system almost immediately. While no official policy specifically addressed the activities of the cadet club within Coast Guard operations, operators in the field recognized the operational value of the team's efforts and integrated the information. Since Hurricane Harvey, the team has conducted digital operations to support rescuers on the ground during responses to Hurricanes Irma (2017), Florence (2018), and Michael (2018).

The Cajun Navy's operations were leveraged by the established response system in 2017 when the Houston Police Department requested operators of small, flat-bottomed boats to assist with rescues. This request served to leverage and legitimize the Cajun Navy's efforts. While it is likely the Cajun Navy would have conducted rescue operations without the request, the leveraging action taken by the established response system paved the way for over 7,800 documented rescues. More rescues, including pets, were probably conducted that were not documented through the Houston Harvey Rescue database. It remains to be seen if the Cajun Navy will continue to be leveraged as a semi-legitimate response organization. However, as the response to Hurricane Harvey showed, a simple request for help may be all that is required to activate a valuable force multiplier.

3. Recommendations

One method to leverage disruptive emergent systems in disaster responses is to examine responses in terms of the five components within the ontological diagram for opportunities. This research revealed that disruptive emergent systems are primarily driven by demands based on survivor needs. This implies that survivor needs need to be understood to be able to leverage a disruptive emergent system designed to meet those needs. During the hurricane responses studied for this research, common needs included rescues, clean water, food, electricity, medical care of some type, basic supplies, and information. To meet these needs, disruptive emergent systems developed capabilities and mechanisms while supporting a humanitarian culture. Each of these components are potential points that may allow the established response system to leverage disruptive emergent systems. The established disaster response system could, for example:

- Leverage capabilities: Social media and mobile technologies are readily available to many people and serve as a primary communications platform for some disruptive emergent systems. Social media platforms should be used to pursue integration efforts between systems.
- Leverage mechanisms: Advanced technologies, like Project Loon or Tesla's battery packs, were used to fill survivor needs. Leverage fast-track mechanisms to enable public-private relationships that can quickly deploy advanced technology solutions. Coordinate at the lowest level to meet survivor needs in a timely fashion.
- Leverage culture: Emergent, self-organized groups that provide needed services to survivors should be supported during disaster responses. Before disaster strikes, however, the established response system should adopt an "all-opportunities" approach to promoting community resilience.¹⁴⁸ This approach focuses on people-centric strengths of communities, which may be very location-dependent.

The capabilities, mechanisms, and culture components all reside on the supply side of the disruptive emergent system ontological diagram. Established disaster response systems can leverage the other side of the diagram to reduce potential demand in terms of conditions and motivations.

- Demand conditions: Investing in resilient electricity generation capacity that does not rely upon a distribution network for fuel or delivery will reduce several immediate needs. Investing in resilient communications networks will provide the ability to disseminate and collect information regarding needs and services. Prestaging supplies with distribution plans in place will also reduce certain demands.

¹⁴⁸ Angela Yvonne English, "People-First Homeland Security: Recalibrating for Community Collaboration and Engagement within a Homeland Security Ecosystem" (master's thesis, Naval Postgraduate School, 2014), <http://hdl.handle.net/10945/44555>, 1.

- Demand motivations: Pre-staging water, food, and electricity generation capacity can reduce initial demand for response services.

Four main recommendations can be derived from this examination of the five ontological diagram components.

- Proactively reduce potential survivor demands before a hurricane strikes. Reducing demands will reduce the need for disruptive emergent systems from the outset.
- During the initial response, provide support or reduce barriers to disruptive emergent systems that are meeting the highest survivor demands. Besides actual rescuers, this will also include crisis maps and other virtual volunteer tools that meet survivor demands. Actively legitimize beneficial emergent systems.
- During the transition to recovery, support the evolving capabilities and mechanisms of disruptive emergent systems. Actively leverage or integrate those capabilities as appropriate, and legitimize the system contributions.
- Throughout the process, identify successful disruptive emergent systems and understand the system capabilities and mechanisms. Use this understanding to smooth the way for future systems that do not have to be disruptive or emergent.

These recommendations, the ontological diagram, and identification methods are the result of an analysis of thirteen disruptive emergent system vignettes from the four costliest hurricanes on record in the United States. Though the hurricanes exhibited a wide range of disaster conditions, this analysis revealed that survivor demands and disruptive emergent system features were similar across the hurricanes. These demands and features represent a new approach to understanding the effect of disruptive emergent systems in present and future disaster response environments.

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IX. CONCLUSION

Disruptive emergent systems within disaster response will supplement, displace, or fill gaps in the response activities of the established system. This research sought to reveal the effects of disruptive emergent systems on the established disaster response system. A series of sub-questions broke down the main research question into effects on previous responses, insights about those systems, and application of those insights to future responses. A total of 13 disruptive emergent systems from four different hurricane responses were analyzed. The analysis showed that disruptive emergent systems are likely to supplement ongoing response activities or fill gaps in those operations. This research also discovered that these systems emerge based on survivor demand conditions and motivations along with available capabilities and culture. How do disruptive emergent systems affect established disaster responses?

A. EFFECTS OF DISRUPTIVE EMERGENT SYSTEMS

What were the effects of disruptive emergent systems on modern disaster responses? The disruptive emergent systems discovered through this research demonstrated multiple operational effects on the established response system. An analysis of the NRF core capabilities and ESFs revealed particular categories of capabilities that disruptive emergent systems gravitated toward during hurricane responses. The common threads within the ESFs and core capabilities were communications, information, and emergency aid.

The disruptive emergent systems studied in this research also had strategic effects on the established response system. The main strategic effects were changes regarding leveraging individual disruptive emergent systems, the use of social media for actionable disaster response, and the decision points to integrate a disruptive emergent system into the established response. In several vignettes, disruptive emergent systems were turned away, discounted, or ignored. However, as the response progressed in each hurricane, the established system recognized the benefit of particular disruptive systems, implicitly imparting legitimacy on those systems. In some cases, the established system leveraged

those disruptive systems by requesting assistance or providing direct support. In other cases, the established system directly engaged in information exchanges with a disruptive emergent system, thereby integrating the disruptive system into the established response.

Finally, the disruptive emergent systems seemed to impact survivor trust in the established response system. This effect was evident through attitudes and actions exhibited by survivors and individuals within several of the disruptive emergent systems. This effect should be examined further through empirical evidence collection and analysis to understand the trust transition beyond anecdotal examples.

B. DISRUPTIVE EMERGENT SYSTEM INSIGHTS

Though the hurricanes exhibited a wide range of disaster conditions, this analysis revealed that survivor demands and disruptive emergent system features were similar across the hurricanes. These demands and features represent a novel approach to understanding the effect of disruptive emergent systems in present and future disaster response environments. Table 14 contains the overall feature list of disruptive emergent systems discovered through this analysis.

Table 14. Final set of aggregated disruptive emergent systems.

Final Aggregated Features
Rapid response time for urgent survivor needs
Reduce gaps in response
Local and external community resilience and solidarity through physical and virtual actions
Humanitarian volunteerism / moral obligation
Agile, decentralized operations for a defined and accepted mission
Grassroots organizational flexibility and resilience
Creative problem solving through operational partnerships and innovative technological solutions
Capability and willingness to leverage technology and partnerships for operations

Reduce gaps in response and rapid response time for urgent survivor needs are features that address survivor demands. These demands, along with the ability to reduce the demands, are essential components to disruptive emergent systems. Without particular demands, there is no need for the responding system. *Local and external community resilience and solidarity through physical and virtual actions* along with *humanitarian volunteerism and moral obligation* serve as components of a motivational culture through which a disruptive emergent system emerges and operates. These culture features are essential enabling components for disruptive emergent systems. *Agile, decentralized operations for a defined and accepted mission* with *grassroots organizational flexibility and resilience* are mechanism features of disruptive emergent systems. These mechanism features are defining features for disruptive emergent systems within hurricane responses. Each system studied exhibited certain levels of each aspect within these features. Finally, *creative problem solving through operational partnerships and innovative technological solutions* with the *capability and willingness to leverage technology and partnerships for operations* represent capability features of disruptive emergent systems. Without these capability features, the disruptive emergent systems would not be able to meet any survivor demands.

The ontological diagram developed from these features reflects the necessary feature components for a disruptive emergent system within a hurricane response. The diagram, shown in Figure 7, is divided into demand and supply sides with conditions and motivations within each. Capability and mechanism components form supply conditions while the ability to reduce perceived gaps in response makes up the demand conditions. Cultural components comprise the supply motivations and the ability to respond rapidly to needs falls within demand motivations. This diagram can be used to understand disruptive emergent systems, recognize the conditions and motivations required for these systems to form, and provide a roadmap for the established response system to leverage these systems.

Disruptive Emergent System Ontological Diagram

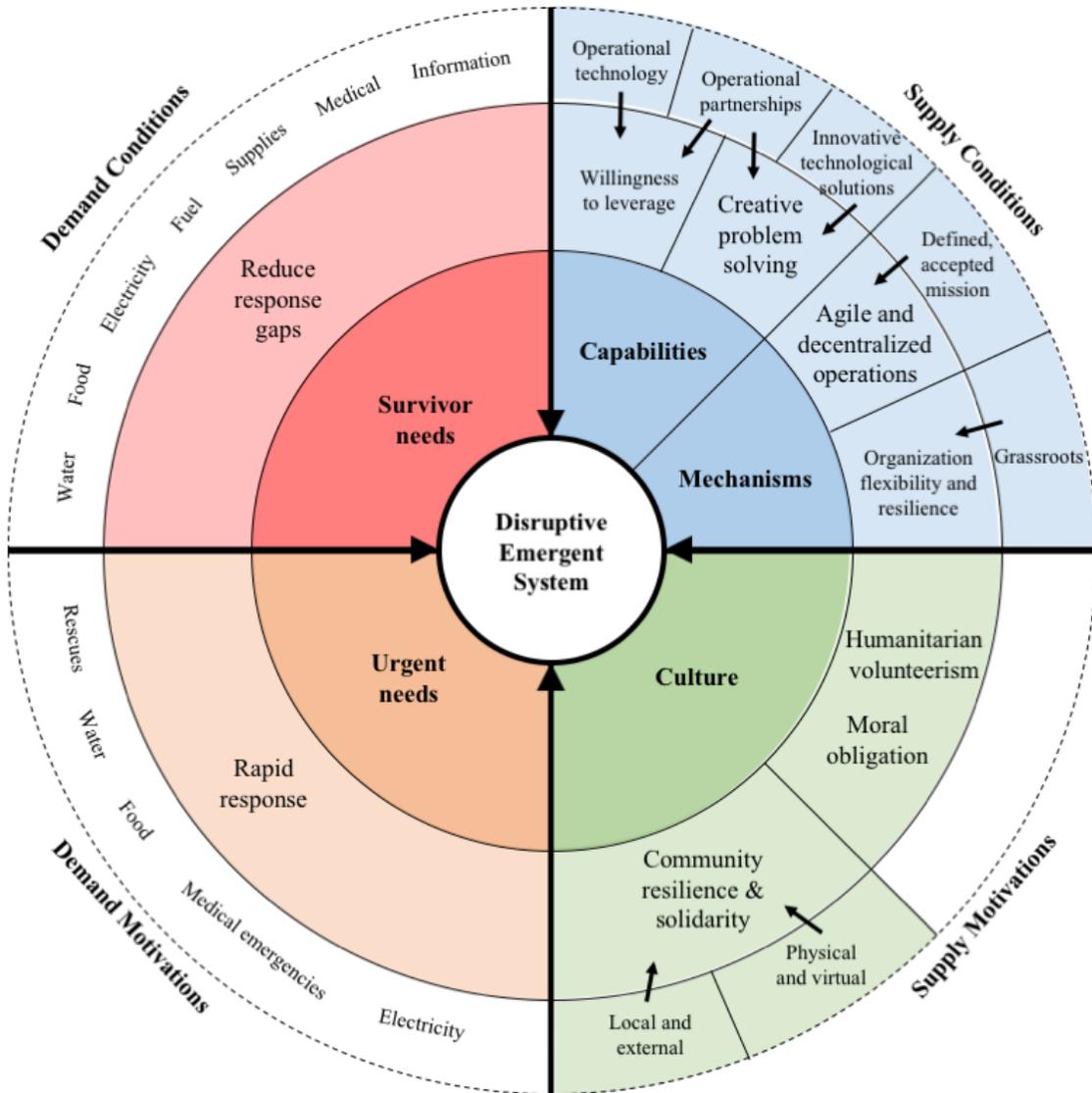


Figure 7. Disruptive emergent system ontological diagram.

C. LEVERAGE DISRUPTIVE EMERGENT SYSTEMS

The disruptive emergent systems studied in this research emerged through particular capabilities, mechanisms and cultural components to satisfy survivor demands. In addition to these insights, several recommendations can be drawn from the results of this research. First, the established response system should leverage disruptive emergent systems by leveraging the capabilities of those systems. Social media and mobile

technologies are readily available to many people and serve as a primary communications platform for some disruptive emergent systems. Social media platforms should be used to pursue integration efforts between systems. Second, the established system should leverage organizational mechanisms of disruptive emergent systems. This may include creating fast-track procedures to enable public-private relationships to quickly deploy advanced technology solutions that normally require lengthy bureaucratic processes. Third, the established system should leverage culture. Emergent, self-organized groups that provide needed services to survivors should be supported during disaster responses.

Along with leveraging the supply side of the ontological diagram, established disaster response systems should consider the effect of potential demand reduction. For example, investing in resilient electricity generation capacity that does not rely upon a distribution network for fuel or delivery will reduce several immediate needs. Investing in resilient communications networks will provide the ability to disseminate and collect information regarding needs and services. Prestaging supplies with distribution plans in place will also reduce certain demands.

Several general recommendations may be drawn from the ontological diagram leverage recommendations. First, predictable survivor demands should be proactively reduced before a hurricane strikes. This will reduce the need for disruptive emergent systems from the outset. Second, provide support or reduce barriers to disruptive emergent systems that are meeting the highest survivor demands during the initial response. These systems are valuable force multipliers and should be used. Third, support the evolving capabilities and mechanisms of disruptive emergent systems, particularly during the transition to recovery. Finally, identify successful disruptive emergent systems and understand the system capabilities and mechanisms throughout the response. The established systems should learn from these successful systems so that future response systems need not be disruptive or emergent.

Disruptive emergent systems within disaster responses are not new phenomena. This research focused on major hurricane responses since the implementation of NIMS to frame the analytic context of the research. However, the NIMS-based analytic frame is not necessary to examine disruptive emergent systems, the effects of those systems, or the

system origins. For example, on September 11, 2001, the largest mass evacuation of an island in history was conducted.¹⁴⁹ After the World Trade Center towers fell, boats began converging on lower Manhattan to evacuate people from the island. This convergence began even before the Coast Guard broadcast a call in New York Harbor for any vessels interested in assisting with the evacuation. In all, between 300,000 and 500,000 people were evacuated by water in the span of nine hours by approximately 150 vessels, including passenger ferries, tug boats, police and fire boats, and personal watercraft. There was no plan for this type of evacuation. All that was necessary to create this disruptive emergent system was the recognition of survivor needs. Those volunteers with motivation and capabilities leveraged the agility of vessel navigation to meet survivor demands. This brief example demonstrates that this model of disruptive emergent systems can be applied to disasters other than hurricanes and outside any reference to the NIMS organizational framework.

D. FUTURE RESEARCH

These ideas and recommendations are new starting points for examining the future of disaster responses and disruptive emergent systems. The ontological diagram developed for this research should be compared against other models of disaster response or organizational structure theory. The ideas and recommendations presented in this thesis represent one viewpoint of a narrow slice of disaster response. Future research areas should include other types of disasters, such as wildfires, earthquakes, inland floods, and tsunamis. Research in these disaster responses should examine the applicability of the ontological diagram. Figure 8 is the general disruptive emergent system ontological model that could be used to explore other disaster responses.

¹⁴⁹ Jessica DuLong, “The 9/11 Rescue That We Need to Remember,” *CNN*, August 20, 2017, <https://www.cnn.com/2017/08/20/opinions/911-boatlift-rescue-opinion-dulong/index.html>.

Disruptive Emergent System Ontological Model

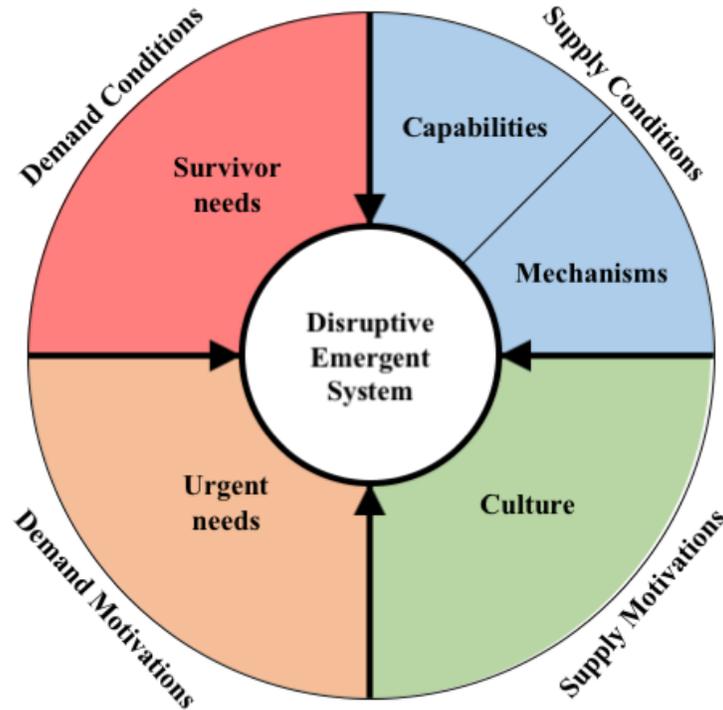


Figure 8. General disruptive emergent system ontological model for future research applications.

Disasters will occur, survivors will have needs, and people will act on their humanitarian nature. These factors, combined with changing capabilities and organizational mechanisms, provide ample opportunity for disruptive emergent systems to arise. Understanding disruptive emergent systems in a greater context will only strengthen our ability to collectively respond when the next disaster strikes.

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APPENDIX. VIGNETTE DATA CODES

A. CODES FOR HURRICANE KATRINA VIGNETTES

“Hard-pressed not to go into action”	Medical aid relief
“Sound of salvation”	Mini-clinic
“The spirit was I’m going to go help”	Mobile clinics
Aid groups	Money
Boats	No FEMA help
Bootstrapped operation	No isolated phenomenon
Cajun Navy credited with saving 10,000 people	No Red Cross
Citizen rescue	Ongoing medical care
Common purpose	Overcoming cultural divides
Community-centered	People requested help by calling in to the radio station
Continued despite dangers, threat of jail	Person-centered treatment
Desire for normalcy: “lock the door”	Positivity
Desperate to be saved, eager to trust	Provisions
Disregard authorities’ orders to return home	Raw human instinct
Donations	Request for volunteers over TV and radio
Emergency Operating Center	Response time
Expected 20–25, got 350–400 boats	Responsibility to act
FEMA assistance	Selfless acts
Fend for themselves	Slow federal response
First aid emergency response	Street Medics
First medical team	Trapped by floodwaters
Free medical treatment	True heroes
Grateful	Volunteers
Hope	Volunteers without authorization
Initial response from volunteers	Wait for rescue
Makeshift flotilla	

B. CODES FOR HURRICANE SANDY VIGNETTES

Ability to volunteer “right now”	Facebook
Ad-hoc group	FEMA
Advertised needs	Filled critical gaps
Airbnb	Filled the void for aid
Amazon gift registry	Food
Amazon.com	Frequent stakeholder interaction
Autonomous relief activities	Frustration with established protocols
Autonomous volunteer action	Gas shortages
Borrowed motor pool	Google Crisis Map
Church as operations base	Grass-roots ethos
Community-based trust	Grassroots disaster relief network
Construction teams	Help pump water from homes
Contact information	Humbled
Cook meals	Idea incubation
Coordinate with other orgs	Improve donation system
Crowd-sourced information	Information requests
Doctors Without Borders	International effort
Donation centers	Inventory management
Donation distribution	Kitchen
Donations	Lagging federal aid
Donations - household goods	Laterally organized rapid-response team
Door-to-door	Leading humanitarian group
Emergent response group	Legitimizes efforts when established groups provide supplies
Emerging type of grassroots relief collective	Limited military assistance
Empower people to solve community problems	Motivated to help
Enabled common operating picture	Mutual aid
Enabled transparency	Neighborhood reconstruction
Enormous organic operation	Network
Established groups slow to deliver aid	No formal organization or structure
Established groups turned away volunteers	NYPD

Occupy Wall Street
Online gift registry for donations
Only people out here - disbelief
Open-source software tools
Organizing
Phone calls
Power
Precedent-setting
Rapid decision making
Rapid information sharing
Readily available opportunities to help
Real-time needs
Real-time updates
Red Cross monetary donations
Red Cross sent blankets to Occupy
Red Cross slow assistance
Relief
Revolutionary for emergency management
Risk taking
Rumor control
Self-organizing
Shipping
Social media
Social movement
Solidarity, not charity
Supplies
Survivor information
Temporary housing
Thwarted attempt at volunteering
Total devastation
Track donations
Trapped in homes / apartments
Trauma support
Twitter
Unfilled desire to assist
Victims

Volunteer
Volunteer brigades for reconstruction
Volunteer information
Volunteer recruiting
Volunteer tasking
website
What do people need most?

C. CODES FOR HURRICANE HARVEY VIGNETTES

911	Flat-bottom boats
Absence of first responders	Geolocated map
Absolute game changer	GIS
Aid neighbors	Glympse
Amateur outfits	Going to lose hope
Assist first responders	Grassroots collective
Base of operations	Heat map
Battery life a valuable resource	Helping people 1500 miles away
Broadcast safety or peril	Humanity Road
Call wait times	Hurricane Katrina
Call-backs	Information broadcast
Chaotic rescues	Instagram
Command Center	Institutional reliance
Congressman contact	Irma
Connection to non-profit organizations	Labor intensive to monitor social media
Crisis-mapping technology	Mapping skills
Crowdsourced information	Meet on social media
Deep motivation to help	Minimal staff
Difficult for EM community to engage with volunteer responders	Mobile rescue command center
Digital Humanitarian Network	Mobilizing rescuers
Digital megaphone	Monitoring social media channels
Digital search and rescue	Moral courage
Digital volunteers	Nextdoor
Dispatching boats	Official requests for volunteers with boats and high-water vehicles
Do it, deal with consequences later	Online database
Don't want to be in the surveillance business	Only National Guard authorized
Donations	Organizational liability
Dropped calls	Organize rescue and recovery
Facebook	Organized citizens can be more effective
Failing gov't bodies	Outdated telephone technology
Federal government is not a requirement	Overburdened first responders

Patriotic solution to crumbling infrastructure	Tribal politics of rescue
Phone lines at capacity	Twitter
Powerless	Unexpected complication
Pressure on megachurch to provide shelter through social media	Untrained dispatcher
Privacy standards	Urgent medical resources
Rapid response	Use all channels available
Real-time information	Vigilante armada
Receiving and deploying inventory	Vigilante humanitarian aid
Red Cross only accepted cash donations	Volume of data challenges
Reddit	Volunteer rescuers
Repeat calls for retweets & posts	Volunteer social media team
Rescuing people in dire need	Waze
Saves lives and saves resources (digital crisis mapping)	We will take care of our own
Saving own team	World-wide volunteers
Service	Zello
Signal boost / retweeting	
SMS texts to 911	
Snapchat Snap Map feature	
Social media as a tool for good	
Social media calls for help	
Social media organization	
Social media posts to locate people in distress	
Software developer in NYC	
Stranded	
Stretched gov't resources	
Strong-willed brave citizens working collectively	
Supplies	
Swift efficiency	
Technology buy-in	
Temporary shelter	
Trapped	

D. CODES FOR HURRICANE MARIA VIGNETTES

Aid delivery logistics	Fuel for generators
Area electric power / grid	Generators
Backup power generator	Government dependence
Balloons	Government partners
Basic cell service	Government response
Basic supplies	Help
Bureaucracy	Hope
Canned food	Information
Cell phones	Investors
Charters	Irma
Checked luggage cargo	Makeshift system
Churches	Medical supplies
Citizens	Message relay
Clean water	Minimizing
Commercial availability	Money
Commercial capacity	Need for supplies
Connectivity	Optimism
Contingency	Overcoming barriers
Creativity with limited resources	Persistence
Critical infrastructure	Personal connection
cucubanos	Positive psychological impact
Deliveries to hospitals	Power
Disaster preparedness	Power oases
Donations	PR as a laboratory
Emergency services	Promised equipment
Energy destiny	Red tape
Experiment	Resilient system
Family	Restore business
FEMA	Retrofitted trucks for food distribution
FEMA supplies	Rural areas
Flashlights	Satellite phones
Food spoilage	Shelters
Food trucks	Solar battery pack
Fresh food	Solar microgrid

Solar mini-grid
Solar panels
Spare parts
Sustained connectivity
Triage
Trucks for distribution
Underserved areas
Unforeseen partnerships
Unreliable power grid
Unresponsive FEMA
Urgency
Vision of the future
Volunteers
Water
Water purification system

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