

Building Resilient Communities Through Geospatial Intelligence

A report by the United States Geospatial Intelligence Foundation (USGIF)





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Foreword

By Dr. David Alexander, chief geospatial scientist and Flood APEX Program Manager, U.S. Department of Homeland Security, Science & Technology Directorate, First Responders Group

We all know and accept that each disaster occurs in a specific location on Earth. We also acknowledge the costs of and risks from disasters are continuing to rise in the United States. This upward trend in U.S. disaster risk is not just of concern to lives and property, but also to our way of life as it threatens the fiscal solvency of the nation. The concept of resilience offers a new approach that is rapidly progressing from theory into policy and practice. This is an important evolution in emergency management. Resilience places renewed emphasis on strengthening all aspects of emergency management (preparedness, response, recovery, and mitigation) for the whole community (governments, businesses, and individuals) with a focus toward actions that can be taken (before, during, and after) that enable an impacted area to better withstand and bounce forward following disaster.

In July 2015, as a result of Hurricane Sandy, the U.S. Government Accountability Office (GAO) issued a report¹ articulating the need for the federal government to establish an investment strategy for enhancing national resilience to future disasters. The report defined resilience as “the ability to prepare and plan for, absorb, recover from, and more successfully adapt to actual or potential adverse events.” In the context of disasters, resilience describes the ability to respond and recover in a manner that minimizes loss of life and property and enables a quick return to normal economic and life activities. As the effects and costs of disasters increase as a result of climate change, disaster resilience will be a

primary means for the federal government to help control its fiscal exposure to disasters, according to the report.

The Federal Emergency Management Agency (FEMA) responded to the GAO recommendation, and in 2017 began to develop a National Mitigation Investment Strategy for strengthening national resilience with the purpose to improve the coordination and effectiveness of mitigation and risk reduction activities across the U.S. This strategy takes a whole community approach to resilience that is applicable to federal departments and agencies; state, territorial, tribal, and local governments; and private and non-profit sector entities such as businesses, philanthropies, foundations, universities, and other non-governmental organizations.²

In support of this strategy, FEMA also issued two new “moonshot” goals intended to help the nation achieve better disaster resilience: doubling flood insurance coverage across the nation by 2023; and quadrupling mitigation investment across all stakeholders by 2023.³ The U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate responded to this national concern with research and development support—issuing a community resilience to disasters topic to explore new technologies and innovations in resilience science and knowledge, risk communication and insurance, and technology and material solutions that could enhance national disaster resilience at all levels.⁴

Achieving resilience requires understanding the totality of circumstances given the various threats, hazards, and risks facing a community and to visualize the actions and preventive measures necessary to avoid, prevent, reduce, or transfer the risks from those dangers. Geospatial intelligence (GEOINT) is a common denominator that allows communities to understand their totality of circumstances—to identify, monitor, and model those dangers to produce vulnerability and risk assessments that can be linked to potential actions targeted to the optimal areas and critical assets that can strengthen a community’s overall resilience. GEOINT also provides a means to understand the social implications of potential disaster to foster a community’s psychological resilience and strengthen its ability to bounce forward and to build a culture of preparedness imbued in its individuals and civic organizations, businesses and critical infrastructure, and levels of government.

This report explores how GEOINT contributes to and can strengthen community disaster resilience. It is hoped the homeland security, emergency management, and geospatial communities will find the substance and recommendations in this report to be of value and assistance toward developing common and effective approaches, spurring innovation in resilience design and solutions, and promoting a culture of preparedness that better readies the nation for catastrophic disasters and everyday emergencies.

1. U.S. Government Accountability Office (GAO). Hurricane Sandy: An Investment Strategy Could Help the Federal Government Enhance National Resilience for Future Disasters. Report to Congressional Requestors. <https://www.gao.gov/assets/680/671796.pdf>. U.S. Government. July 2015.

2. Federal Emergency Management Agency (FEMA). Draft National Mitigation Investment Strategy. https://www.fema.gov/media-library-data/1515688801146-ef9a42945d292dc6848dc4390dc0b032/Draft-National-Investment-Strategy-for-Public-Comment_Jan2018.pdf. U.S. Government. April 2017.

3. Federal Emergency Management Agency (FEMA). 2018-2022 Strategic Plan. https://www.fema.gov/media-library-data/1533052524696-b5137201a4614ade5e0129ef01cbf661/strat_plan.pdf. U.S. Government. March 2018.

4. U.S. Department of Homeland Security, Science and Technology Directorate (DHS S&T). Topic: Community Resilience to Disasters. DHS S&T Funding Opportunities website. <https://baa2.st.dhs.gov/>. U.S. Government. June 2018.

Executive Summary

By Talbot Brooks, Delta State University

Resilient communities withstand and resist adverse change imposed by emergencies in a manner that minimizes loss and hastens an expedient and full recovery. This may be construed as encompassing the full life cycle of emergency management. Similar to national security interests, resilient communities must assess risk and plan for adverse events, take affirmative steps to mitigate threats, respond appropriately when the crisis is at hand, and efficiently deploy resources for recovery. Such similarities provide an opportunity to share and adapt national security and civilian applications to community resilience.

Geospatial intelligence (GEOINT) is “the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth.”¹ GEOINT emerged from the national security community to assess risk, facilitate strategic and tactical planning, support field operations, and provide humanitarian assistance. In recent years, GEOINT has become mainstream, supporting a variety of commercial applications, from precision agriculture and community land use planning to disaster response and emergency management. In its current state, GEOINT has emerged as an invaluable tool for disaster management, demonstrating tangible benefits toward enhancing capabilities and infrastructure in the advent of more frequent catastrophic disasters. One can expect this trend to endure as GEOINT continues to permeate society, technology, and practice, thereby strengthening our overall resilience and enabling the next generation of public safety professionals.

The United States Geospatial Intelligence Foundation (USGIF) was selected by the United States Department of Homeland Security (DHS) to explore the rapidly evolving domain of GEOINT

as it relates to community resilience. USGIF conducted an initial assessment of current GEOINT use in partnership with the National Alliance for Public Safety GIS (NAPSG) at the 2017 National Geospatial Preparedness Summit (NGPS) on 7 Aug. 2017 in Tuscaloosa, Ala. A half-day workshop was held as part of the greater summit.

Participants were provided with presentations that covered contemporary uses of GEOINT and then led through a series of thought exercises by which they could identify parallels within the full range of their current activities in the disaster/emergency response space. A subsequent exercise facilitated group discussion whereby both emerging trends in geospatial technologies and high priority application areas were identified for the purpose of organizing and writing a report. While enthusiasm for the idea resonated among participants, none were willing to engage longer term to create the report.

Subsequent discussions with participants revealed the following:

1. Participants did not have time to contribute longer term. While most communities are aware of the value of geospatial technologies, their implementation is often limited to the department providing funding support for hardware, software, personnel, and training. This limits the range of activities in which a geospatial professional may participate.
2. Participants faced challenges in engaging others across their community. Return on investment in geospatial resources is difficult to assess, especially when preparing for disasters that occur at sporadic and unpredictable intervals. It can be difficult to convince others about the importance of participating in the use of geospatial technologies to build resiliency.

3. Participants had a difficult time relating resilience to geospatial technologies. A community's creation and implementation of resiliency strategies is often incomplete or unbalanced because geospatial dimensions are not considered. Resilience as policy and practice is still emerging and ill-defined for most communities.

These responses indicated that the principle barrier to the use of geospatial technologies for improving community resilience lies in underlying knowledge gaps and silos. Barriers to collaboration hinder the resilience building process.

The state of GEOINT for community resilience is thus rooted in the development of otherwise unlikely partnerships that extend beyond obvious emergency response roles. It will be necessary for the whole community to create and maintain opportunities across unlikely stakeholders. Using geospatial technologies as a vehicle for exploring and improving resiliency between tax assessment and similar local government departments, private utility providers, the insurance industry, the health industry, academia, agricultural interests, and more opens scores of possibilities. Challenging these new partnerships to push beyond contemporary definitions of community, to take on shared ownership of resiliency, and to work together creates a shared interest and common identity.

GEOINT methods and practices are adept at cultivating these types of collaborations and facilitating the transfer of knowledge. This report highlights those cases in which innovative organizations and communities have undertaken such steps to advance resilience utilizing GEOINT and looks to them as precursors to the future of GEOINT for community resilience.

1. Title 10 United States Code §467



From Military to Community Resilience

By Talbot Brooks, Delta State University

The concept of resilience among the United States Armed Forces has historically focused on the ability of a combat unit or system to sustain damage without compromising operational integrity. Strategies for building resilience have focused on armored resources, rigorous training, and academic programs for senior leaders that emphasized war gaming and planning exercises focused on potential future events. The importance of these activities cannot be understated as the consequences of fielding a military that is not resilient jeopardizes the effectiveness of the U.S. to forcefully enact policy, risks the depreciation of public trust and support through unacceptable losses, and, most importantly, unnecessarily risks the lives of warfighters and citizens.

Any military campaign is fundamentally a geographic exercise. To most combatant commanders, understanding and maintaining situational awareness and mastery of terrain is critical for success. A small, well-equipped fighting force with mastery of the battlefield can often outmaneuver larger forces, move more swiftly, and adapt to changing conditions. Geospatial intelligence (GEOINT) has been a critical element of American military superiority and America's existence as a country. These roots can be traced back to George Washington,

who may be most famous as the first U.S. President, but had he not overwhelmed the odds for success against the British as general of the Continental Army, a much different history might be in play today.

Washington was a master tactician of the battlefield. Students of the Revolutionary War know Washington was, by trade, a surveyor for a significant portion of his early career. This experience led him to intuitively understand how a map represents terrain and he was able to deploy troops successfully as such. He tasked Robert Erskine, geographer and surveyor general to the Continental Army, to complete more than 200 maps and put them to use to outmaneuver enemy forces. At larger scales, Washington employed the genius of Alexander Louis Berthier, who separated geographic features into layers drawn upon hinged panes of glass.¹ These panels could be removed or rearranged to provide a means to geographically study the battlefield. Washington and French general Comte de Rochambeau employed Berthier's maps during the battle of Yorktown to calculate the firing trajectories required to destroy the enemy and to identify blind spots where enemy canons would be ineffective.

Such applications quickly impressed

upon the U.S. military the value of what would become known as GEOINT, and are often cited as the earliest notional developments of a geographic information system. The conceptual leap from content that only included terrain to that which included climate and weather patterns and other features associated with physical geography helped commanders decide how to better equip and train troops such that they would succeed in a given environment. Soil samples from the beaches of Normandy were secretly collected prior to the World War II D-Day Invasion. These samples were analyzed to determine how much they might compress under various weights, and the results were used to determine areas suitable for wheeled and tracked vehicle traffic. Conversely, both Chinese and U.S. forces neglected to properly account for terrain and weather at the Chosin Reservoir during the Korean War. Troops are now more resilient because they are better physically conditioned, equipped with weaponry, and fortified with GEOINT such that they are "hardened" against the environment.

The effectiveness of GEOINT in improving resilience finds its origins in early maps and geographic thinking and is applied as readily to battlefield casualties. The

1. Foresman, T. (1998). GIS Early Years and the Threads of Evolution. *The History of Geographic Information Systems: Perspectives from the Pioneers*. New Jersey: Prentice Hall. 3 pp.

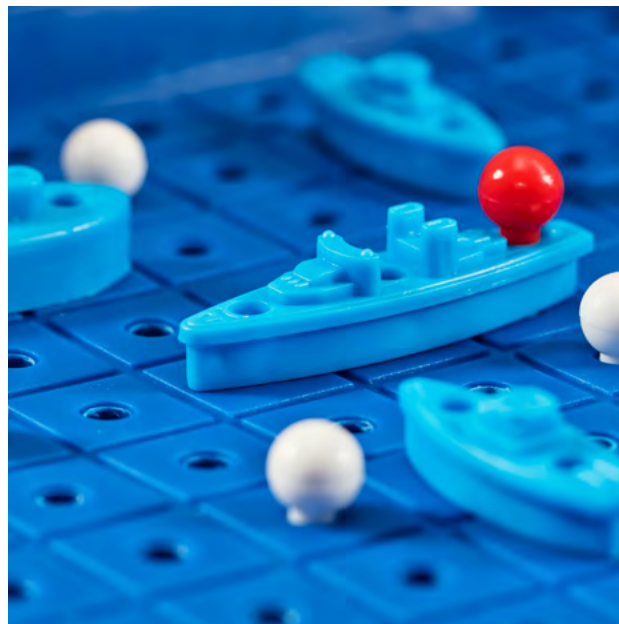
success of General Ulysses S. Grant's campaigns is as often attributed to his military genius as they are to the overwhelming superiority of available manpower during the American Civil War. Both President Abraham Lincoln and Grant realized that success in the Civil War relied on continued Northern public support for the war such that volunteers could be continuously raised and public will sustained. This simply would not have been possible had the already abhorrent number of deaths climbed higher. Thus, efforts to save the lives of wounded soldiers carried not only a moral impetus, but a political one as well.

GEOINT enabled several battlefield innovations. Hospitals, doctors, and nurses were positioned far to the rear in early Civil War battles. The required time to travel such distances often led to fatal outcomes. Jonathan Letterman, the medical director for the Army of the Potomac, studied maps and developed a system of field triage stations, ambulance systems, and evacuation plans whereby wounded soldiers were moved from immediate, but lower intensity care facilities to those offering greater capabilities. This innovation helped reduce casualties and provided an important secondary effect: wounded or ill soldiers could be returned to service more quickly, slowing the drain on personnel resources as the conflict raged on.

The use of GEOINT to deploy medical support to the battlefield, along with medical advancements, contributed to the concept of the "Golden Hour," or the belief that a patient suffering serious traumatic injury rapidly declines if he or she is not presented to an appropriate-level trauma service within an hour. Controversy surrounds 60 minutes as a hard and fast rule, but the concept of administering treatment as quickly as possible remains. Contemporary planning for the delivery of emergency medicine to

the military relies heavily upon GEOINT to calculate potential evacuation times and consequently affects other aspects of field deployment and resource provisioning. Resilience is improved through the ability to not just prosecute the war but to recover more quickly from aftereffects or losses.

War games have long captivated the imagination and extended beyond military environments into living rooms through board games such as Hasbro's famous "Risk." Movie fans are likely familiar with Matthew Broderick's



moment of terror when WOPR, a fictional computer used by the American military to simulate nuclear war, asked "Shall we play a game?" in the 1983 film titled "WarGames." Games are a means of simulating war scenarios without risking lives. They are conducted routinely using maps and have long been a part of military planning. The rise of powerful computer systems, such as those highlighted in "WarGames," are increasingly tied to geography through the advent of GIS and now play a common role in battlefield planning and training exercises.

The ability to alter the geographic conditions under which war is waged helps better inform planners, and the significance of such systems gave rise to the Training Transformation Program (T2) program at the U.S. Department of Defense. Simulators now help train militaries around the world for war, and all of them rely upon GEOINT systems to not only correctly display the terrain, but to provide the underlying realism needed to create everything from bumps in the road to equipment failure due to environmental conditions. Beyond saving money by reducing the need to deploy troops to an actual field training site and the accompanying wear and tear on manpower and equipment, this type of GEOINT-enabled war simulation helps identify where new techniques and strategies are needed. This improves resilience by identifying where and when military leaders may need to adapt plans and policies to deal with current and future conditions.

The use of GEOINT improves the resilience of a military force by improving its ability to operate in tough environments, recover quickly from loss, and adapt to conditions yet unknown. While the vernaculars may be different, community resilience to disaster shares similar objectives to military resilience: know and understand the location; harden critical infrastructure and populations against a given threat; design systems and plans to enable a fast response and recovery; and employ adaptive strategies to reduce future impact. The portability of GEOINT for improving resilience from the military domain to that of a community is fundamentally one of altering the underlying scenario from conflict to disaster. It also offers renewed opportunities to strengthen the communities of practice through shared lessons learned. ◀



The Informed Emergency Manager

By Dr. David Alexander, chief geospatial scientist and Flood APEX Program Manager, U.S. Department of Homeland Security, Science & Technology Directorate, First Responders Group; and Talbot Brooks, Delta State University

Emergency managers of the future will become more and more informed by geospatial intelligence (GEOINT). This better-informed emergency manager will be a key factor in driving resilience across the whole community. Geography is the single greatest determinant of a community's disaster resiliency—the ability to resist, recover, and adapt to disaster and its risk of occurrence. The means and degree by which geography affects community resiliency is a function and consideration of scale. The types of potential disasters faced by a community are determined by and assessed at small geographic scales (regions). Climate data clearly demonstrates that tornados are far more prevalent in Nebraska than southern California but can occur in both geographies. Conversely, significant earthquakes are more probable to occur in southern California than in Nebraska; while disasters like flooding are more spatially concentrated based on physical geography and human settlement patterns.

Understanding the risks associated with a particular geographic region proportionately translates into investment in resiliency from an “ability to resist” perspective. Communities in Nebraska are more likely to have tornado-focused building codes and storm warning sirens designed to prevent loss of life and property, whereas those in California will

expend resources to harden structures against earthquakes and install seismic monitoring systems. The consequence is that Nebraskans are less able to resist the effects of an earthquake and Californians less able to resist those of a tornado. Meanwhile, communities more susceptible to flooding might focus their attention on flood protection mitigation and land-use ordinances requiring development above base flood elevation.

The traditional means of understanding the risk of differing types of disaster and creating accompanying mitigation strategies that enable a community to resist the effects of a particular mode of disaster are largely based upon historic records, communal memories, and physical evidence of prior catastrophe. The hazard risk reduction process is designed around a community's ability to come together to understand its risks and enact plans that result in a prioritized expenditure of finite resources to limit loss. This has historically occurred through public meetings whereby a table of prior events might be presented in concert with a few disaster photos and anecdotes. Discussion ensues and priorities for threat reduction are set that are often as rooted in emotion as they are actual risk.

GEOINT serves to better inform this process through the integration and

visualization of risk. It provides an analytic and viewing framework to drive decision-making based upon data. The potential for violent loss of life and property from an earthquake or tornado easily captures the imagination and often drives risk reduction strategies to the top of priority lists. The use of GEOINT in disaster planning scenarios clearly demonstrates that the loss of life and property due to flooding is more prevalent and more spatially concentrated.

GEOINT enables the use of complex, geographically-based models to assess, visualize, and present risk such that data-driven decisions may be made. Current GEOINT approaches are still limited in their effectiveness due to uncertainties related to modeling natural events and our ability to create truly engaging maps and visualizations. Improved processing power and algorithms combined with the integration of time into 3D mapping systems are rendering GEOINT an increasingly effective tool set for reducing risk through the application of resistant strategies. This fosters the growth of adaptive strategies at the community level by unifying the perspectives of various stakeholders toward common goals and objectives.

The effectiveness of using GEOINT to

improve resiliency transcends community and neighborhood levels to regional and national scales. It also extends beyond adaptive and coping strategies to include response and recovery activities. GEOINT works at these levels by mapping the location of prior emergency incidents by type, overlaying them with demographics and terrain, and combining them with threat and hazard profiles to produce risk landscapes. It may then be used to extend the process through the exploration of resource routing, the placement of key facilities, the impact of closures and weather, and more. It provides a way to start integrating disparate and difficult to comprehend data into a comprehensive tool for guiding effective and rapid decision-making.

GEOINT is a useful tool for disaster and emergency managers at the specific location of an individual incident or structure. Geography plays a crucial and central role at this largest of map scales in which quickly comprehending “where” is essential. Knowing how much hose to pull to reach a hydrant, how many people are needed to haul an obese patient a given distance, where to establish cordons to contain a criminal on the loose, how many search teams are needed to comb through wreckage, and much more are all dependent upon geography.

The use of GEOINT products as simple as a sketch of a building or a topographic map greatly facilitate the ability of an emergency manager to function effectively and act quickly. Time is the enemy during disasters. A home fire doubles in size every 30 to 120 seconds, depending on the combustible material involved. The faster the fire department is able to respond and extinguish the fire, the lesser the degree of loss and, in turn, the faster the recovery. The use of GEOINT to perform the aforementioned complex analytic and modeling tasks for a wide variety of circumstances facilitates the creation of adaptable response plans that serve to limit loss. In the fire service, these plans are called running orders and pre-plans, but all aspects of emergency and disaster response have their analogous forms. Law enforcement call them crime analysis maps that are used to alter patrols and beats, emergency medical services call them staging maps that are used to pre-position ambulances based upon time, and disaster managers use them to manage search and rescue and similar tasks. The future in this domain is the application of artificial intelligence and machine learning to consume an ever-increasing quantity and complexity of data to enhance the GEOINT picture.

New and emerging geospatial intelligence capabilities are having a dramatic impact on the emergency management domain. The use of drones and unmanned vehicle systems allows emergency managers to limit the exposure of responders to hazardous conditions, to see around corners and around buildings, and to use infrared imagery and other remote sensing techniques to see what ordinarily cannot be seen. Use of indoor LiDAR, a system that uses lasers to map interiors, permits the construction of virtual realities in which responders may practice their trade in preparation for real events—and do so at a fraction of the cost of a “live” drill. Moreover, these practices help inform adaptive practices and allow managers to better understand recovery needs quickly and thoroughly.

Location is the fundamental tenet underlying the roles and responsibilities of an emergency or disaster manager. A community is less resilient simply through the absence of consideration of geography when preparing for, responding to, and recovering from an incident. The possession and use of GEOINT is therefore a component of resiliency in and of itself and a fundamental tool for the informed emergency manager. ◀





GEOINT for Disaster Operations

A FUNDAMENTAL ASPECT OF COMMUNITY RESILIENCY

By Dr. Kumar Navulur, Sr. Director, Global Business Development, DigitalGlobe

Any strategy on community resilience should include the fundamental components of disaster operations: resist, respond, recover, and adapt. To resist is to acknowledge that a disaster will occur and to take corresponding actions to harden people, places, and systems against damage. Resistant actions may include implementing building codes that require the use of roof straps and “hurricane-proof” glass in new construction, building sea walls to minimize the effects of hurricane-driven waves, and similar. Response is the ability to mobilize the resources and capabilities immediately needed “to save lives, protect property and the environment, meet basic human needs, stabilize the incident, restore basic services and community functionality, and establish a safe and secure environment moving toward the transition to recovery.”¹

Recovery as it relates to resilience is more than simply rebuilding. It is the speed at which a community restores and then improves upon what was lost such that it may better withstand future disasters. Recovery time is essential, and, in some instances, this may mean rebuilding an area to be less vulnerable to future events. Adaptation tends to be a longer term strategy. It involves shifting toward

an attitude and understanding that not only better prepares a community to resist and recover, but also to collaborate and evolve with risk.

Scenario 1: A Miami Hurricane

All four aspects of resiliency are about to be tested in the following hypothetical disaster scenario. At 08:00 on Aug. 29, 2019, the National Oceanic and Atmospheric Administration’s (NOAA) Geostationary Operational Environmental Satellite 16 (GOES-East) beams a series of full-disk (half of the planet) images back to the National Hurricane Center (NHC) in Miami, Fla. The NHC imagery processor adds these latest images to an animated series taken at 30-minute intervals for the past three days and activates an artificial intelligence (AI) trained through machine learning to recognize cloud motions that suggest the formation of a tropical cyclone. The algorithm recognizes a pattern 450 nautical miles west of the coast of Africa and near the equator—a pattern otherwise indiscernible to the human eye—and automatically calls for and analyzes secondary data sets from GOES-East Band 10 (lower-level atmospheric water vapor) and Band 11

(cloud top temperatures), and queries NASA’s Aqua satellite for sea surface temperatures and Jason-2 for weight height data. These data confirm the probability that a tropical cyclone is forming at greater than 60 percent and an alert is sent to the on-duty NHC meteorologist.

The meteorologist compares the computer’s findings with previous forecasts, which had hinted that a storm might form and, using the Geophysical Fluid Dynamics Laboratory (GFDL) forecast model, plots a likely track for the following days. She initiates a coordination call with the Navy’s Second Fleet Weather Center at Norfolk Naval Station in Virginia. The Navy checks the Statistical Hurricane Intensity Prediction Scheme (SHIPS) model running at Stennis Space Center to create an intensity forecast and launches a Predator drone to investigate from the USS Gerald Ford, which is on station near the Azores. The USS Colorado, a fast-attack submarine, launches two unmanned underwater vehicles in the path of the storm to begin collecting surface weather condition data while the NHC initiates high-resolution simulations using a suite of models to create a

1. National Preparedness Goal. <https://www.fema.gov/national-preparedness-goal>

consensus track and determine intensity for the next 96 hours.

The models indicate a 70 percent probability that Miami will be struck by Hurricane David at Category 4 intensity in 88 hours. A C-130 Hurricane Hunter aircraft is scheduled to launch from Keesler Air Force Base in Mississippi to investigate further. Storm warnings are issued by the NHC, and Florida's Emergency Response Team uses geospatial information about population and transportation networks to issue preliminary evacuation orders and pre-position search and rescue teams and supplies just out of harm's way. Sandbags are distributed and plywood flies off the shelves as locals begin boarding up windows. A total of 12 hours has passed since the storm was first noticed.

This might sound futuristic, and while the workflows might deviate from actual current processes, this is the current state of GEOINT as it applies to disaster operations for hurricane events. The objective is to provide residents enough warning to secure their homes and businesses such that they might recover quickly by minimizing loss and then evacuate such that life is preserved. Immediately after the storm strikes, the process still relies more heavily on direct observations by humans, but technological advancements are quickly changing this balance.

Returning to our scenario, the navigation systems in cellphones and automobiles already transmit information about the rate of progress along evacuation routes, and re-route evacuees as roads become congested. Traffic, police, and news camera feeds across Miami feed into the Emergency Operations Center (EOC), and real-time analysis yields estimated wind speeds and flood depths. Utility companies begin reporting the location of power outages, a decrease in cellphone voice and data traffic, and a loss of internet connectivity. GEOINT professionals analyze all of these data and more to help disaster managers prioritize where to send rescuers when conditions begin to abate.

Imagining the immediate future, a fleet of drones is launched as soon as winds diminish enough for safe flight and their activities are coordinated by artificial intelligence. The imagery from these drones is combined with other geospatial information in near real-time to classify the degree to which damage occurred and compare it with tax assessor, utility, and Census population maps. This automated analysis is used to authorize the release of federal disaster assistance for affected areas, expedite delivery of disaster relief to affected homeowners, and guide search and rescue crews. It is also used to quantify infrastructure damages, for example, providing the power company a count on the number of telephone poles damaged and the miles of wire in need of replacement, and offering waste management an estimate of the amount of debris to be removed. These data would be shared using common exchange standards through EOC and used to sequence and coordinate response and recovery activities like sheltering and mass care, power restoration, and to advise residents when they might be allowed to return home.

Scenario 2: Wildland Fire

Turning to a wildland fire scenario provides a broader perspective as to what is possible in the near future. Understanding forest fuel types is an initial step that requires maps of the potential areas of fire, terrain and how it affects fire propagation, vegetation type, vegetation health, and exposed structures. High-resolution satellite imagery with spectral bands that range across visible, near-infrared, and short wave infrared can be analyzed over impacted areas using existing AI and machine learning techniques to extract these features. Stereo pairs may be created from these imagery sets or LiDAR may be used to map terrain. Hyper- and multi-spectral imagery may be used to identify and calculate the volume of water resources that can aid in forest firefighting. Infrastructure such as buildings and rooftop material, roads

and other transportation features, rail, landing zones for helicopters, power lines, and other similar pertinent features can be derived and provided as GEOINT products to incident management teams.

Where AI and machine learning techniques are not reliable enough, incident managers may turn to the "crowd" by asking professional societies, college students, and GEOINT hobbyists to analyze imagery and digitize features using portals such as Humanitarian OpenStreetMap. These data can be combined with evacuation zones and shared with cellphone providers who use automated dialing systems to alert persons at risk.

Short wave infrared images and mid-wave sensors can penetrate smoke and haze to identify hot spots and extreme fire behavior. These data may be collected using a variety of platforms including satellites, drones, and high-altitude balloons. The resulting data may be used to predict the immediate path of the fire and estimate potential loss.

After the fire passes, local authorities can deploy social media apps for use by citizens on the ground to gather photos and videos to enhance the common operating picture. A portal with citizen-sourced data can be made available to compare before and after imagery. This aids managers, insurance companies, and citizens in assessing the location-specific status of their properties. For severe fires, a program can be created post disaster to understand the environmental impacts and estimate the threats of landslides and flash floods using similar sources of data and modeling techniques.

The aforementioned scenarios provide a showcase of current and soon-to-be-available capabilities. In the current and future state of disaster operations, we will see a fusion of numerous innovations occurring across the emergency management domain like those described in the preceding scenarios. Technological developments in cloud storage and computing will be implemented, making massive,

comprehensive data sets accessible to various stakeholders across the globe. High-performance infrastructure from cloud computing providers such as Amazon Web Services, Google Cloud, and Microsoft Azure will be employed, along with investments in AI and machine learning algorithms that can derive insights at scale. Analytical procedures leveraging these native algorithms will be incorporated, next to the data, to provide various stakeholders with actionable, near real-time location-based information (GEOINT), while providing future insights in a timely manner. Common operating

pictures for various stakeholders will leverage GEOINT from multiple sources and become essential for communicating various steps and progress during emergencies. Policies will be updated to allow for more cooperation with industry through established agreements that overcome issues with data sharing, storage, compute, and access. The ensuing public-private collaboration will ensure successful execution of emergency response and recovery programs. These actions will speed recovery and thereby improve overall community resilience.

Community resilience is only limited by our willingness to embrace the means and measures, many of which are GEOINT-based, by which we may better collaboratively employ the concepts of resist, respond, recover, and adapt. Achieving the future envisioned will be incumbent upon all stakeholders to avoid a failure of imagination—to embrace the possibilities—and to plan integrated implementations, collectively build and use the resultant systems and data, and update policies to reflect ongoing innovation. ◀



The Underlying Fabric of Our Society

CRITICAL INFRASTRUCTURE RESILIENCE RELIES UPON GEOINT

By Xavier Irias, East Bay Municipal Utility District

Resilient strategies for critical infrastructure, the systems that make modern society possible, must include strategies that minimize their exposure to disaster, facilitate speedy recovery, and educate the public about how to survive when systems are damaged or destroyed. U.S. critical infrastructures are often systems within systems and are embedded elements of the geographies that make up our cities and towns, counties, states, and nation. They include:

- Health infrastructure such as emergency response, hospital, and pharmaceutical systems

- Communications infrastructure such as telephone, data, and radio systems
- Transportation infrastructure such as networks of roads, waterways, rail systems, and airports

Failure of critical infrastructure systems are often the reason a disaster becomes a disaster. Whether a community's electric infrastructure fails on a brutally cold winter's day due to the accumulation of ice from a winter storm or as the result of a fire in an aging transformer that should have been replaced years ago is almost irrelevant as the consequences are much

the same. A lack of investment in critical infrastructure systems makes them particularly vulnerable to disaster as old and worn-out parts are far more prone to failure.

The American Society of Civil Engineering (ASCE) evaluated the condition of U.S. critical infrastructure and awarded it a grade of "D+" in 2017. These systems can be said to underlie modern society, not merely in the figurative sense but quite literally. Many of the systems supporting civilization lie buried and unseen beneath our cities: pipes that bring safe, clean water to our homes;

1. Infrastructure Report Card. As provided by the American Society of Civil Engineers and viewed at <https://www.infrastructurereportcard.org/> in July 2017.

electrical power lines and gas lines that enable heating, cooking, transportation, and more; and sewer systems that protect society from dangerous wastes and floods.

Infrastructure systems are also systemically and geographically complex. Systems rely upon systems which rely upon systems—failure of one often has cascading effects. For example, a train derailed and caught fire in a tunnel under Howard St. in Baltimore on July 18, 2001. The fire, which burned for five days, was incredibly intense and melted fiber-optic communications lines and caused a 40-inch water main to rupture. The flood from the water main did not put out the fire, rather the water ran in a different direction and into an electric power substation, causing it to fail. The resulting mess shuttered businesses in downtown Baltimore for days, fouled up East Coast rail traffic for weeks—causing a temporary auto parts shortage in Asia, and crippled transatlantic internet traffic carried by WorldCom for 36 hours. The economic impact quickly soared into the hundreds of millions. The Baltimore Orioles baseball team, for example, lost \$5 million due to cancelled games alone.² Among the important lessons learned was that resiliency efforts must consider not just system age and design, but also geography. Had Baltimore realized that all of these systems intersected at one location, mitigation efforts would have prevented such cascading failures.

Infrastructure owners and operators recognize the dependence of society upon critical infrastructure, and thus the need to improve resilience in this area. Improving resilience in the context of infrastructure involves a few strategies:

- Improving the ability of the infrastructure to resist damage, and to function to a degree even when damaged
- Improving the repairability of infrastructure
- Improving the ability of society to function with impacted infrastructure

- Improving and rebuilding aging and outdated infrastructure

Geospatial intelligence (GEOINT) provides several important tools to support these critical infrastructure resilience strategies. For example, GEOINT allows infrastructure networks to be planned for maximum survivability by, when possible, avoiding geo-hazards (that is, hazards with a geographic component, such as earthquakes, landslides, and flood zones). When geo-hazards cannot be completely avoided, geospatial tools can help locate assets in a fashion to permit quicker repair. For example, it is better for a pipe to cross an earthquake fault at a perpendicular angle than to be oriented in a somewhat longitudinal direction that subjects the pipe to compression during an earthquake. Repairing the former is fairly simple whereas the latter would require the replacement of long sections of pipe. Moreover, infrastructure designers should recognize the need to use earthquake-resistant pipe in such an area.

GEOINT can also ensure damaged infrastructure functions to a degree when possible. For example, if a water system is damaged during an earthquake, critical backbone pipes must remain functional to support basic firefighting and life-sustaining uses even if other pipes are ruptured. Geospatial technologies allow damage to be mapped quickly so ruptured pipes can be isolated by opening and closing valve works, thus allowing parts of the network that are not damaged to continue functioning. Several water utilities, including the East Bay Municipal Utility District (EBMUD), are formalizing this concept. A “resilient water network” is one that resists damage, can function to a degree when damaged, and can be repaired in a prioritized fashion so a community’s essential needs can be met quickly, even if full restoration takes a longer period of time.

Converting existing water networks into resilient networks will involve a mix of

several GEOINT-based approaches, including:

Identifying low-reliability pipes.

A low-reliability pipe might be unreliable under all conditions, or unreliable only when subjected to a shock such as an earthquake or landslide. GEOINT tools are used to gather information about existing pipe networks, including the corrosion potential or seasonal movements of surrounding soil, landslide occurrences, test data or other observations on pipes themselves, and more.

Identifying the highest priority pipelines. These tend to be pipes that are not only unreliable and prone to failure, but also pipes that are important—serving particularly vital needs such as hospitals or concentrated populations. GEOINT allows planners to overlay and analyze disparate data sets such as socioeconomic data, land-use data, and details about critical infrastructure to help identify the highest priority investments.

Replacing low-reliability pipes. Once a pipe has been selected for replacement, geospatial technology plays a huge role in replacing the pipe in a way that minimizes impact on the community served. For example, GEOINT is used to assess pipeline replacement routes through the identification of sensitive areas such as the habitats of endangered species that must not be disturbed by construction, other sub-surface utilities that must be avoided, and other planned work that might present an opportunity for low-impact project phasing. For example, if a GEOINT analysis indicates that a water pipe, a sewer pipe, and a roadway project are all planned in the same area, performing all three elements in a coordinated fashion is less expensive and less disruptive than carrying out each project in isolation.

Adding isolation valves. When a pipe network is broken, it is usually necessary to turn off or turn down the flow to the broken pipe. This enables repair and

2. U.S. Department of Homeland Security (2001). US Fire Administration Technical Reports Series, CSX Tunnel Fire: Baltimore Maryland, USFA-TR-140/July. Washington, DC.

reduces water loss. The more strategically placed valves are available for isolation, the smaller the area affected by a break. GEOINT can help identify locations where valves can provide the most value by helping to quickly model the population impacted by a given pipe break under a variety of different valving scenarios.

GEOINT is also used in the day-to-day operation of water systems. Climate change is causing more frequent droughts and floods, which, in turn, place an increased strain upon water systems. GEOINT may be used to estimate the potential for drought or flood by measuring the potential for the melting of snowpack in the spring. Water

system managers may then implement appropriate adaptive strategies to deal with any resulting drought or flooding. Both use cases require GEOINT to ensure society's need for water is reliably met.

GEOINT provides critical information for water utilities serving communities across the nation and greatly enhances the resilience of water supplies. It is integral to ensuring resiliency for every aspect of providing a safe water supply: planning the infrastructure comprising the water system; building or renewing the infrastructure; maintaining it; and operating it. The result is a greater level of resilience through the construction of elements better designed to withstand

disaster, such as smarter designs, the use of tougher materials installed at the most vulnerable locations, and the incorporation of adaptive strategies that facilitate faster recovery from loss.

The infrastructure community has a long and rich history of utilizing GEOINT to support the critical infrastructure lifelines that make up the underlying fabric of our society. There is also widespread acceptance that GEOINT provides essential tools and technologies for optimizing and implementing critical infrastructure resilience. Achieving critical infrastructure resilience both now and in the future will most certainly rely on GEOINT. ◀



Staying Connected

THE IMPORTANCE OF RESILIENT COMMUNICATIONS

By Dr. Robert Austin, Austin Communications

Communications systems are the backbone of all aspects of disaster management and their post-disaster recovery is the top priority after ongoing loss of life and property has ceased. This is largely because communications systems in disaster management are a dichotomy: they are not only the physical infrastructure by which we communicate information; they are the notional means by which we communicate information for and about communicating information. This rings particularly true when applied to geospatial intelligence (GEOINT) because the data sharing and

collaborative efforts required for effective GEOINT are not possible without communications systems, and spatially-based products and services are most valuable when shared widely and used to create a common geographic frame of understanding.

The physically complex nature of and need for resiliency in modern communications systems is most readily understood through Emergency 911 (E911). The objective of E911 is to use a single, nationally consistent telephone number to quickly and seamlessly route

calls for emergency help to the correct answering point of service such that the jurisdiction having authority for any given type of emergency may be dispatched to the caller's location. This system is semi-autonomous and removes the guesswork of pre-E911 days when someone in need of help had to know what telephone number to call based upon their location and the nature of their emergency (police, fire, EMS). That an E911 system must be 100% reliable and funded primarily through a tax on telephone service is a massive undertaking—just returning the tax money collected from cellphone users

to the proper communities is a mind-boggling task.

Understanding the basics of E911 provides a reference point for how GEOINT is used to ensure resiliency in communications and emergency systems. All wire-line (landline) telephone numbers are entered into a database called the Master Street Address Guide (MSAG). Each entry is matched to an address and given an Emergency Service Number (ESN) that corresponds to the emergency service agencies having jurisdiction for the location of that telephone. E911 calls originating from a wire-line device are automatically routed, based upon telephone number dialing prefix, to a pre-assigned public safety answering point (PSAP). An automated number identification/ automated location identification (ANI/ ALI) system accesses the MSAG, looks up the telephone number provided by the ANI/ALI, matches it to a location, and passes this information to an E911 operator when they answer the incoming call. Cellphone calls automatically embed the geographic coordinates of a caller and are captured by the closest tower, which then routes the call to a pre-assigned PSAP. The location information, originating telephone number, and ESN are all automatically populated into the E911 operator's computer.

The E911 operator then interviews the caller, determines the disposition of the call and what resources are needed, and alerts the appropriate emergency response agency based upon ESN. This alert is done using complex radio and data systems with their own geographically-based routing rules for transmitting voice and data. The Telecommunications Act of 1996 established regulatory performance targets for call processing, geographic coverage, and location accuracy for E911 service areas for both wire-line and wireless carriers. The Wireless Communications and Public Safety Act of 1999 (The 911 Act) facilitated the

prompt deployment of a nationwide, seamless communications infrastructure for emergency services that included wireless communications. During the 2000s, the National Fire Protection Association (NFPA) also established a benchmark for response: that 90% of all fire-related emergency calls must be answered, processed, and dispatched to the jurisdiction having authority within 64 seconds of when a caller dials 911, and the fire department must be on scene and ready to initiate action within a total of 384 seconds.¹

Redundancies are built into an emergency communications system to account for potential failures and make the system more resilient. For example, MSAG databases are replicated in real-time across multiple PSAPs using private computer networks relying upon multiple modes of communication (e.g., microwave, fiber-optic, cable). Common backup radio frequencies are identified and programmed into responder radio systems. Telephone switches automatically re-route calls should an ANI/ALI fail. All of these redundancies enable one community's PSAP to automatically receive calls for a neighboring community should its system fail. These processes become infinitely more complicated as the number of jurisdictions cooperating and the number of potential incidents increase.

E911 applies GEOINT to bridge communications and emergency response systems. The most basic geographic requirement for any E911 systems remains: put a point representing a caller's location inside an area representing an emergency response organization's jurisdiction. This tenet enables a host of other, more advanced applications as they relate to communications systems such as automated public alerts and warnings using GEOINT and reverse 911 functionality. For example, poisonous gas that is lethal within seconds can be a by-product of the gas wells in the prairies

of Alberta, Canada. TELUS, the telephone provider for the area, has created a reverse E911 system whereby if a leak is detected, an automated system identifies the location of the incident and calls every telephone within a predetermined evacuation area. The U.S. uses a similar GEOINT functionality within the National Emergency Alert System (NEAS) to enable a variety of public notices on potential dangers such as weather, toxic spills, or other incident types. Examples include the National Weather Service (NWS) delivering severe weather alerts via cellular and text messaging and the U.S. Geological Survey (USGS) sending earthquake alerts in a similar fashion. All these communications capabilities improve community resilience by yielding faster response times in relation to an emergency or impending disaster. The faster an event is mitigated, the less damage done and the faster the road to recovery.

FirstNet, 5G, and Fundamentals

Disruption to communications can have cascading and disastrous effects compounding the impacts of an emergency. The 2016 Great Smoky Mountains wildfires near Gatlinburg, Tenn., provided a case study in the importance of communications for firefighters and other first responders. Fire and high winds destroyed cell towers, melted fiber-optic cable, and disrupted digital communications. Analysis after the events revealed the weaknesses of the communication system in this disaster, weaknesses that could have been addressed by using geospatial and communications technologies in partnership.

The national public safety community is hoping to address the types of weaknesses in communication resilience (interoperability, redundancy, availability, etc.) that occurred in Gatlinburg with the FirstNet system. As defined by the system developers,

1. National Fire Protection Association (2015). NFPA 1710: Organization and Deployment of Fire Suppression Operation by Career Fire Departments. Quincy, MA. 75 pp.

"The FirstNet mission is to deploy, operate, maintain, and improve the first high-speed, nationwide wireless broadband network dedicated to public safety. This reliable, highly secure, interoperable, and innovative public safety communications platform will bring 21st century tools to public safety agencies and first responders, allowing them to get more information quickly and helping them to make faster and better decisions."

FirstNet is being deployed using existing facilities and newer facilities built—using geospatial technologies in the communications network design—specifically for the purpose of providing a system designed *"for public safety by public safety [professionals]"*¹

The growth of the world's wireless communication networks has been remarkable for its speed and its widespread, almost ubiquitous distribution. GEOINT continues to play a role in the further evolution of this global communications market. The next generation—Fifth Generation (5G)—of wireless networks will create a demand for new and enhanced geospatial

information systems. With speeds of up to 100 GB per second, 5G will be as much as 1,000 times faster than 4G, but is sufficiently different technically from current technologies to create a new class of concerns in network construction.

Major U.S. cellular carriers are investing in developing and testing 5G systems, which will operate in the 28 GHz and 39 GHz bands of the electromagnetic spectrum. Use of these portions of the spectrum, combined with the nature of 5G technology, means 5G signals will not travel as far as 4G signals. This, in turn, means wireless carriers will need to densify and augment their backbone networks of cell towers. Additionally, they will need to augment the expanded and densified network backbone with small cell networks, sometimes referred to as picocell networks, and local area optical fiber networks to distribute 5G signals—at their fullest capacity and speed—in urban areas. This is where GEOINT plays yet another role: terrain modeling, line-of-sight analysis, and nearest-neighbor analysis—fundamental geospatial technologies—will be critical

for this engineering work. A new class of geospatial analytical tools will be needed to optimize the effort and to build and design new strategies for resiliency.

Communication networks do not function independently of other infrastructure networks that support modern life. Communication systems are built in three dimensions and constitute one of the largest real-world manifestations of physical networks. They extend beyond obvious elements such as telephone lines, cell towers, broadcast media, and fiber-optic data cables to include the private networks used to operate automated teller machines, automated systems used to deliver utilities, and systems like GPS that supply positioning, navigation, and timing services.

Professionals in the field of critical infrastructure protection employ the concept of "infrastructure interdependency," which recognizes that the failure of any given piece of infrastructure often will impact one or more other pieces of infrastructure. For example, consider the effects of a disruption in a regional power supply as shown in Table 1.

Table 1. Cascading Effects of Infrastructure Failure²

SCENARIO	1ST ORDER EFFECTS	2ND ORDER EFFECTS	3RD ORDER EFFECTS
A disaster causes a power supply disruption	Communications: Disruption of calls	Network Operations Center: Limited communications	Emergency Response: Response disruption or delay
	Water Supply: Disruption of water pumps	Medical Facilities: Loss of water supply	Medical Treatment: Limited medical care
	Gas/Oil Supply: Disruption of production pipelines	Cogeneration: Reduced power	Gas Production: Loss of fuel
		Storage Terminals: Disruption of fuels	Transportation: Disruption of travel
	Transportation: Closed roads	Signaling & Switching: Disruption of travel	Goods Delivery: Financial losses, food shortages

The immediate impacts—the 1st Order Effects—are significant in their own ways. More importantly, each set of 1st Order Effects impacts, in a cascading fashion, not only the adjacent cells in the same row but all cells to the right. For example, a disruption in a communications network can affect network operations centers and the ability of citizens to communicate. More significantly, a communications disruption can affect

methods of dispatching emergency services, and therefore the ability of first responders to provide public safety and lifesaving care as well as to communicate with each other.

Resilience is planned for all contemporary infrastructure networks such as communications, transportation, electricity, water, and other utilities. Resilience is accomplished primarily

through the ability of the system to sustain damage using increased redundancy and to quickly recover lost elements. This is reflected in the creation of a nationwide Incident Command System (ICS) that was established in the U.S. after the passage of the 2001 Patriot Act. As part of this system, detailed Emergency Service Functions (ESF) were defined for incident management. The Federal Emergency

1. <https://www.firstnet.com/>

2. Austin, R.F., DiSera, D.P. & Brooks, T.J. (2015). *GIS for Critical Infrastructure*. Boca Raton: Taylor and Francis, Figure 1.3.

Management Agency's (FEMA) "ESF-2: Communications" document addresses the following concerns:³

- Coordination with telecommunications and information technology industries
- Restoration and repair of telecommunications infrastructure
- Protection, restoration, and sustainment of national cyber and information technology resources
- Oversight of communications with the federal incident management and response structures

Similar definitions exist for other infrastructure networks. The principle of infrastructure interdependency has spurred the creation of geospatial tools and technologies to facilitate information exchange and collaboration during

network recovery efforts. A symbiosis exists in the way users of geospatial technologies depend on communications networks—for data storage, data sharing, and data access. All first responders know that the ability to provide their services typically depends on some combination of geospatial and communications technologies, even if only in their vehicle dispatch systems. They need to know where, what, and who.

Community resilience is enhanced through the application of GEOINT to communications systems in two fundamental ways:

1. Improving the physical resiliency of a communications system through redundancy and ease of repair, such that the full spectrum of communications needs is always met.

2. More efficiency and enhanced capabilities within the communications systems to provide geo-targeted alerts and warnings about an impending disaster and to aid in reducing loss by improving response through the better routing and provisioning of resources.

The need for improved communications resilience has spurred U.S. investment in the FirstNet system to ensure reliable public safety communications, and the application of GEOINT will help FirstNet achieve this goal. Other initiatives, such as smart cities and the intelligent transportation system, are also relying on communication resilience to succeed. GEOINT will remain critical to communications resilience and is an important tool for addressing ongoing challenges as technical sophistication, the number of potential failure points, and the number of users ever increases. ◀



Finding the Weak Spot

A GEOSPATIAL AND SOCIAL SCIENCE APPROACH TO UNDERSTANDING AND REDUCING VULNERABILITY

Dr. David Baylis, University of Arkansas, Little Rock

All horror and disaster movie fans are familiar with the classic movie trope: several soon-to-be film casualties make poor choices in the face of death and disaster. While it may be easy to sit back as amateur film critics and mock these poor choices, emergency responders know these films aren't too far off from

reality. People make seemingly irrational calculations about risk all the time. Learning what can be done to prevent this will help disaster managers better understand the decision-making process associated with risky behavior in the face of disaster to better mitigate against it, respond to it, and rapidly recover.

The social sciences have much to say on this subject, specifically in terms of how individual perceptions of risk are produced and how these collectively add up to a culture of risk that can vary dramatically from place to place.⁴ The geographic variation in the perception and culture of risk, and the need for

3. Federal Emergency Management Agency (2008). *Emergency Support Function Annexes: Introduction* (online).

4. Wisner, B., Blaikie, P., Cannon, T. & Davis, I. (2014). *At Risk: Natural Hazards, People's Vulnerability, and Disasters*, 2nd Edition. Routledge.

place-sensitive reaction and targeted response, lends itself to another valuable approach—a social scientific framework.

After highlighting a few key social science insights into risk, a general discussion of the value of geospatial intelligence

(GEOINT) as an approach for crafting better mitigation, response, and recovery strategies is presented.

Figure 1. Modified Risk Triad (UN-SPIDER) with inclusion of three other social science risk analysis domains¹



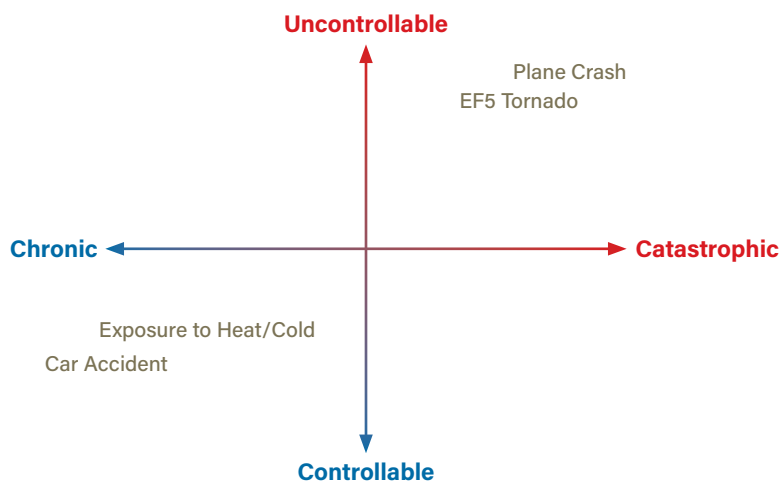
Social and Cognitive Factors That Influence the Perception and Experience of Risk

Prior experience and access to information (or misinformation) are powerful social factors shaping how risk is perceived. Risk is highly subjective and influenced by an array of cognitive biases that create unique challenges for emergency managers. Consider the persistence of common misconceptions regarding what to do in the event of a tornado and how to protect yourself if driving when a tornado strikes. Viral

video footage of the use of highway overpasses as impromptu shelters has erroneously reinforced this as a proper safety precaution, despite the deaths of three individuals who sought shelter in such locations during the May 3, 1999, tornado outbreak in Oklahoma. Lack of knowledge or misinformation regarding the particular dynamics of a specific hazard are merely one dimension of risk perception. Figure 2 demonstrates how

risk perception might be diagrammed based upon whether an individual thinks he or she has control and choice in that situation, and how hazardous he or she perceives the situation to be. Hazards that are seen as uncontrollable and catastrophic tend to be viewed as riskier, despite statistical evidence to the contrary.

Figure 2. Perception of Risk²



1. Robbins, P., Hintz, J. & Moore, S.A. (2013). *Environment and Society: A Critical Introduction*, 2nd Edition. John Wiley & Sons.

2. Slovic, P. (1987). Perception of Risk. *Science*, 236(4799), 280-285.

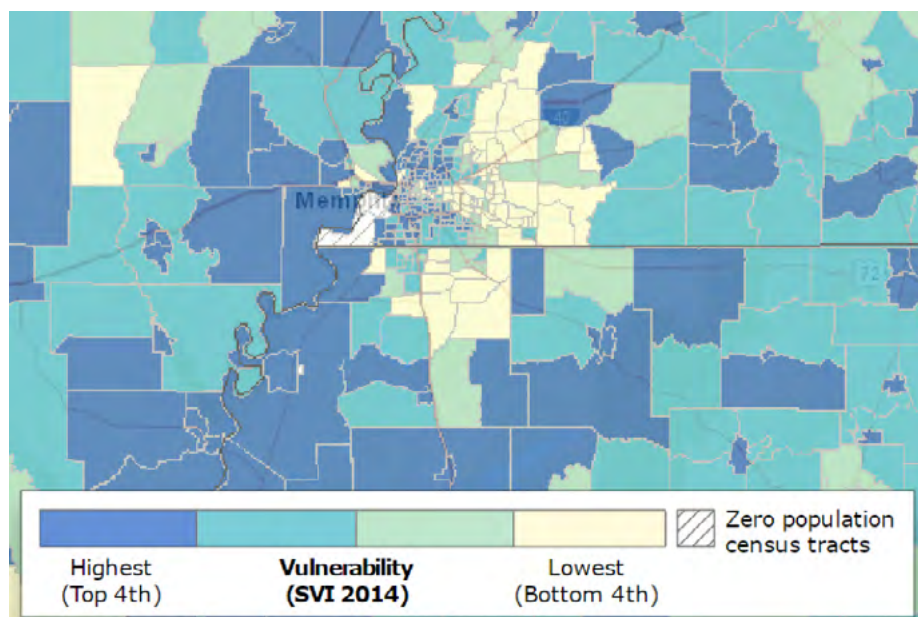
GEOINT is especially useful to this process because it displays multiple layers of relevant information for analytical purposes. Overlays of socioeconomic stress, population density, and land use and building type can be used to identify areas in which first responders should aim to provide assistance as early as possible due to the higher likelihood of vulnerability. Voter and other demographic information might

be useful for indicating common cultural and identity characteristics of particular areas and, consequently, perhaps attitudes toward hazard preparedness.

The U.S. Centers for Disease Control and Prevention (CDC) uses a GEOINT-based approach to explore the social factors that contribute to a community's disaster vulnerability. CDC's objective is to improve community resilience by establishing programs that address

social vulnerability, as doing so reduces suffering and decreases the cost of recovery after a disaster. CDC created the Social Vulnerability Index (SVI), a derivative of 15 geographic layers based upon Census data such as education, family characteristics, income, access to a vehicle, and similar. The metric is stratified into four levels ranging from the most to least vulnerable and mapped by Census tract as shown in Figure 3.

Figure 3. Social Vulnerability Index (SVI) for metropolitan Memphis, Tenn.³



Understanding Community Nuances

Since “community” is a subjective term, it is essential to understand how it manifests in place in order to highlight important human capital assets at the center of communications and local power networks. Understanding these relationships from a geographic perspective is especially important for shaping resilient attitudes before a disaster, as mindset should govern educational approaches. These networks are also essential for rapid resource allocation, building trust, and gaining access, especially in marginalized areas or relatively closed communities.

This was made evident following the Haitian earthquake of 2010 in which local knowledge and ground support proved crucial for lifesaving efforts. A socially and culturally nuanced approach can help practitioners ensure the information they gather is timely, relevant, and accurate and that they are able to expediently craft the right message for the right place and context.

The Haitian earthquake makes an excellent case for the value of socially nuanced and place-specific geospatial literacy in the context of hazard response and mitigation. While the earthquake devastated large parts of Port-au-Prince, it soon became clear that the

confusion caused by the extensive damage to buildings and infrastructure was compounded by the lack of accurate and accessible maps of the area. Free and open access mapping tools such as OpenStreetMap proved an important means for bringing together volunteer mappers, translators, and first responders to generate what has been lauded as the most complete, accurate, and up-to-date computerized map of Haiti's transportation grid.

This early example of volunteered geographic information (VGI) combined with social media was invaluable to rescue and relief efforts in Haiti. However, its contributions should not be limited to

3. As viewed at <https://svi.cdc.gov/map.aspx>

hazard response; they can be augmented by the social scientific insights discussed above and extended to mitigation and recovery efforts as well. The goal should be not only to provide critical support in real time, but to use this knowledge to reduce hardships to begin with and to help produce stronger and more resilient communities.

Consider the impact of risk perception and cognitive bias discussed above with respect to the issuance of a tornado warning to those on a highway. While it might seem most effective to create evacuation plans using low-cost or minimum-distance approaches, individual perceptions of intervening opportunities (highway overpasses, for example) might inadvertently short-circuit such a route. Sending geo-targeted public service announcements via radio or smartphone could encourage individuals to locate the safest possible shelter,

dispel misinformation, and inculcate best practices in a variety of emergency situations.

Even the successful example of VGI and social media use in Haiti reveals opportunities for systematic improvement based on the linked insights of the social sciences and GEOINT. While immediate disaster relief and humanitarian aid is most important in the hours and days following an earthquake or flood, knowledge about the location and status of local businesses and industries is essential for helping to jump-start the local economy and improve the likelihood of rapid recovery and self-sufficiency. Using a combined social science and GEOINT approach can assist communities in finding the weak spot; for example, to aid planners in creating an inventory of assets essential to community health and well-being and to create plans to ensure these operations

are up and running as quickly as possible (e.g., the clearing and restoration of vital infrastructure and the provision of logistical support for reconnecting these operations to the community). Such an approach would also help ensure that resilience plans incorporate community insight and local definitions of need into the planning effort.

These are merely a few possible avenues that demonstrate the valuable overlap between the social and geospatial sciences in the context of risk assessment. It is essential that both policy-makers and practitioners understand the social and behavioral factors that shape risk—how it is perceived and how it is manifested in place. These insights are perhaps most powerful when coupled with the visual representations, context, and information conveyance that GEOINT provides. ◀



Climate Change

A DISASTER IN SLOW MOTION

By Dr. Juan Declet-Barreto, Union of Concerned Scientists

Community resiliency strategies for coping with climate change require not only resistive methods, but adaptive strategies that anticipate the longer term and inevitable nature of climate change. The slow nature of these changes will require intergenerational commitment among communities. The perils of climate change as related to disaster are slow

to take hold and will manifest directly through increases in the number and severity of natural disasters and indirectly through civil unrest and conflict resulting from scarcity of resources. Both are geographic problem sets and are rooted in the fact that increasing temperatures will fundamentally alter the hydrologic cycle—producing more heat energy in the

atmosphere, increasing evaporation rates, melting ice caps, altering ocean currents, and intensifying weather. Geospatial intelligence (GEOINT) provides the ability to monitor these climate changes and relate their effects to potential consequences using geographically-based modeling and simulation. The consensus of the scientific community,

as summarized by the U.S. Geological Survey,¹ is that climate change will have the following effects:

1. The increased probability of droughts and floods associated with the strengthening of episodic ocean current events such as El Niño and the Pacific Decadal Oscillation.
2. Increasing intensity of tropical cyclones, which are driven primarily by sea surface temperature, and thunderstorms, which are fueled by the buoyancy of moisture-laden air.
3. Altered food security and increased famine through changes in arable land available for agriculture.
4. Increased coastal flooding, particularly during storm surge events.

The effects of climate change will manifest through heightened event frequency at locations already susceptible to natural disasters and an increased potential for occurrence at locations previously thought immune to them. Climate change models, while far from perfect, are spatially-based simulations driven by location-specific information to forecast longer term changes in weather patterns. These models are effective tools for crafting strategies that may help communities plan proactively and implement a wide range of adaptive measures. Such planning may involve significant undertakings such as a graduated relocation of the population away from future flood-prone areas (through buyouts), retrofits that raise building stock to higher ground, or more subtle approaches such as stronger building codes and enhanced flood proofing (allowing structures to withstand harsher conditions and greater forces).

GEOINT is particularly useful for exploring and incorporating adaptive strategies for climate change into

community resilience plans. The revolution in small, low Earth orbit, near real-time persistent satellite observation is driving new innovations in weather forecasting, climate modeling, and atmospheric and terrestrial monitoring. New global analytic and catastrophic modeling capabilities provide higher resolution and predictive capacity for use at global, national, regional, and now community scales.

A traditional geographic modeling tool such as the Federal Emergency Management Agency's (FEMA) multi-hazard risk assessment and loss estimation software (HAZUS-MH) offers an example of how GEOINT may be used to simulate damage from earthquakes, tsunamis, floods, and wind. HAZUS-MH is particularly effective because it incorporates current geographic data layers such as terrain, the location of structures and their construction type, and the location and hardness of critical infrastructure, then uses predicted storm and flood intensities to predict loss. Simply altering the input geographic layers to match projected growth and running those conditions against predicted storm and flood intensities is one of many available GEOINT approaches to forecasting the effectiveness of adaptive strategies.

Climate change is an incremental process with effects that are felt disproportionately in economically depressed geographic regions most vulnerable to flooding, drought, famine, and cyclone. These regions often lack the financial resources to act as well as the rigorous building codes and sustained infrastructure used in the developed world. They also lack the technical capabilities to employ GEOINT models to simulate adaptive strategies that can best utilize their limited resources. This has promulgated a dire set of secondary

effects: civil unrest, food insecurity, and conflict in the developing world. Rear Admiral David Tittle, a professor of meteorology at Pennsylvania State University, notes: "One of the components of climate change that makes it a threat or a risk to national security is [that] it can make already tenuous, or frankly bad, places much worse and, occasionally, catastrophically so. So much depends on local governance, on the inherent strength and resilience of the communities affected."²

An added advantage to leveraging GEOINT is it can be used to discover ill effects not previously considered. This may be done by establishing relationships across the full range of stakeholders in a community and using a collaborative approach to share data, which improves GEOINT processes. The "Plan Integration for Resilience Scorecard Guidebook,"³ produced by Texas A&M University with funding from the U.S. Department of Homeland Security's Science and Technology Directorate, provides communities with a framework for how to spatially evaluate across various stakeholder plans to align common goals and objectives and better optimize risk reduction investments to reduce overall hazard vulnerability. This approach combines community data collected at different spatiotemporal scales by different agencies with that collected by industry and infrastructure operators to identify areas at the intersection of social-environmental risk and link desired outcomes with policy goals that can drive more effective resilience investment. For example, many Gulf Coast communities, already facing chronic exposure to petrochemical toxins, were recently burdened with acute exposure as 2017's Hurricane Harvey forced emergency shutdowns of multiple facilities, emitting large amounts of toxic pollutants into the air in a short period of time.⁴ Applying

1. The USGS website, https://www.usgs.gov/faqs/how-can-climate-change-affect-natural-disasters-1?qt-news_science_products=0#qt-news_science_products, serves as a general portal from which this information is summarized as viewed in July 2018.

2. Wernick, A. (2017). *The U.S. Defense Department Takes Climate Change Seriously*. Living on Earth (serial). As broadcast on 8 October 2017.

3. For more information about the "Plan Integration for Resilience Scorecard Guidebook," visit [http://ifsc.tamu.edu/getattachment/News/July-2017/Plan-Integration-for-Resilience-Scorecard-Guidebook/Scorecard-\(1\).pdf.aspx](http://ifsc.tamu.edu/getattachment/News/July-2017/Plan-Integration-for-Resilience-Scorecard-Guidebook/Scorecard-(1).pdf.aspx)

4. Hurricane Harvey Magnifies Climate and Petrochemical Toxic Risks for Environmental Justice Communities in Houston. 2017. <https://blog.ucsusa.org/juan-declet-barreto/hurricane-harvey-magnifies-climate-and-petrochemical-toxic-risks-for-environmental-justice-communities-in-houston>.

the GEOINT approach championed in the Texas A&M guidebook would unite a broad spectrum of stakeholders to align interests that could serve to mitigate these types of unforeseen effects, making the community more resilient.

Combining Census socio-demographic data with built environment indicators

from remotely-sensed data at fine spatial scales (e.g., Census Tract) can help identify people and places most vulnerable to regional climate change impacts, inform climate adaptation plans, and provide valuable information for public health officials and urban planners to increase population resilience under a changing climate.¹ Moreover,

GEOINT provides the toolset by which such complex information may be shared and more readily understood because it uses a visual, geographic approach. The ultimate objective is to reduce vulnerability and improve future outcomes—ergo, to build community resilience. ◀



A Smaller World

GLOBAL COLLABORATION FOR RESILIENCY

Dr. Shirish Ravan, United Nations Platform for Space-Based Information for Disaster Management and Emergency Response (UN-SPIDER)

Disaster resiliency is improved by reducing the need to render assistance, harbor and feed displaced persons, recover, and build back better. To achieve these outcomes requires enhanced situational awareness of disaster conditions and cascading impacts. The sharing of geospatial intelligence

(GEOINT)-based information across a wide variety of organizations helps countries more readily combat disasters by helping disaster managers identify, better understand, and mitigate potential effects. The increasing number of disasters around the world, as shown in Table 1, has fueled the need for

greater international collaboration for the collection, sharing, and analysis of space-based data among the agencies that typically operate satellites and organizations concerned with climate change and disasters.

Table 1. Disasters by United Nations region, 1974-2003²

	1974-1978	1979-1983	1984-1988	1989-1993	1994-1998	1999-2003
Africa	88	113	128	107	149	333
Americas	99	199	255	319	320	475
Asia	220	336	353	482	449	726
Europe	43	108	136	144	134	288
Oceania	47	56	57	64	64	75
World	497	812	929	1116	1116	1897

1. Declet-Barreto et al. (2018). Mapping Extreme Heat Vulnerability in Support of the District of Columbia's Climate Adaptation Plan. <https://thrivingearthexchange.org/wp-content/uploads/2016/03/TEX-DC-Policy-Brief-2018-01-31.pdf>

2. Guha-Sapir, D., Hargitt, D. & Hoyois, P. (2004). Thirty years of natural disasters 1974-2003: The numbers. Centre for Research on the Epidemiology of Disasters at Universitaires de Louvain. UCL Presses, Belgium. 190 pp.

The rapid growth of the satellite industry during the past decade has expanded the number of Earth-observing systems from a mere handful collecting primarily low-resolution imagery at infrequent intervals to dozens that collect a wide variety of remote sensing data at high resolution on a daily basis. During this same time period, disaster response organizations have matured significantly, recognizing the value of space-based data, and increasingly using satellite data for all phases of disaster management. For example, federal incident management teams are now staffed with at least one person who can provide geospatial support for an incident.

The growing use of GEOINT by disaster managers is creating shared experiences across a global domain as international partnerships connect otherwise disparate organizations and systems in common cause. In doing so, disaster managers are learning to better use satellite-based data as new technologies emerge. For example, microwave and synthetic aperture radar (SAR) systems may be used to “see” through clouds and detect flooding during and after a storm, thermal imagery may be used to detect spot fires ahead of an advancing wildfire, and multi- and hyper-spectral imagery may be used to search for the specific spectral signatures of objects such as a downed aircraft or a lifeboat lost at sea. Such practical experience helps disaster managers better understand capabilities so they know what to ask of GEOINT resources.

The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), administered by the United Nations Office for Outer Space Affairs (UNOOSA), facilitates international partnerships and development of policy and institutional arrangements globally. The International Charter “Space and Major Disasters” (International Charter), a key disaster response mechanism that emerged through the UNISPACE

III conference hosted by UNOOSA, enables member states to contribute and receive satellite data at no charge. Many commercial space operators, such as Planet and DigitalGlobe, also contribute to the International Charter.

These collaborative frameworks enable countries to take full advantage of GEOINT in national-level efforts related to building disaster resilience. They also play a crucial role in sharing best practices from the international community with national stakeholders. When a major disaster occurs in a nation, the International Charter is activated by an authorized user. Among several other resources, the Charter uses U.S.-based resources such as the U.S. Geological Survey’s (USGS) Hazards Data Distribution System (HDDS) as a centralized clearinghouse to share GEOINT with nations lacking capacity.

The following two case studies offer a glimpse into the ways GEOINT is used to help specific geographies become more resilient through partnerships among international agencies, national institutions, and the disaster management agency of the government.

Enabling the Disaster Management Centre of Sri Lanka to use space-based information for emergency response

Exceptional rainfall had caused widespread flooding and landslides, and the government needed assistance determining resource requirements for responding to the disaster. UN-SPIDER’s regional support office in Sri Lanka, the International Water Management Institute (IWMI), activated the International Charter³ through the Sentinel Asia.⁴ This activation was done at the request of the Sri Lankan Disaster Management Centre (DMC), a governmental unit operated by the Ministry of Disaster Management (MoDM). The Japan Aerospace

Exploration Agency (JAXA) had a satellite overhead and was immediately able to capture and share cloud-free imagery of affected areas. The DMC Relief and Emergency Unit used the resulting maps produced by IWMI to support rapid impact assessment and disaster response. The information was also shared with other relevant authorities to improve decision-making.

In May 2017, UN-SPIDER played a critical role in supporting flood disaster relief in Sri Lanka by requesting USGS again activate the International Charter on behalf of the DMC. In this instance, USGS expertise and resources were able to assist with data distribution and analysis for the DMC.

These two examples demonstrated the value of GEOINT to the government of Sri Lanka, which requested a UN-SPIDER technical advisory mission to help them learn more about this approach. As a result, DMC became an authorized user of the International Charter, which means DMC can activate this mechanism independently. To build further resilience in the country, Sri Lanka is now implementing a national spatial data infrastructure (NSDI) at the recommendation of the UN-SPIDER technical advisory mission. This NSDI is a unique effort since it is driven by the DMC in partnership with other organizations.

Bridging the gap between scientific organizations and Nepal’s disaster management agency

Glacial Lake Mapping and Glacial Lake Outburst Flood (GLOF) risk assessment in the Hindu Kush Himalayas (HKH) is one of the main tasks of the International Centre for Integrated Mountain Development (ICIMOD) in Nepal. Increasing risk of GLOFs is a main concern in the HKH region. Approximately 200 glacial lakes have been identified as potentially critical, but

3. <http://www.un-spider.org/advisory-support/emergency-support/10323/floods-and-landslide-sri-lanka>

4. http://global.jaxa.jp/article/special/sentinel_asia/index_e.html

the real risk of these lakes bursting their dams remains largely unknown. ICIMOD is actively trying to solve this problem by mapping risk in collaboration with national partners. The project aims to assess GLOF hazards from potentially dangerous lakes and investigate vulnerable downstream areas so a resiliency strategy may be created.

However, Nepal's Ministry of Home Affairs and National Emergency Operation Centre (NEOC), the country's main agency for emergency response, has limited GEOINT capacity. In August 2017, higher than normal rainfall and temperatures caused many flood events. After receiving a request from the NEOC for satellite-based monitoring of the

floods that affected 27 districts of Nepal, UNOOSA/UN-SPIDER activated the International Charter and European Commission Copernicus Emergency Management Service (Copernicus EMS) on behalf of the office of the United Nations Resident Coordinator in Kathmandu. ICIMOD served as the project manager, producing and sharing maps with NEOC.¹ These efforts prompted the evacuation of communities further downstream and guided ongoing monitoring efforts.

Global collaboration frameworks are making the world smaller through common cause, shared experience, and knowledge and information sharing, promulgating better international

resilience. This benefits both the developed and developing world. The International Charter has provided timely GEOINT support to the U.S. for every presidentially-declared disaster since Hurricane Katrina in 2005. When local, state, and federal resources are unable to meet needs, local disaster managers and leaders in the U.S. may request GEOINT support and assets associated with the International Charter, UN-SPIDER, and UNOOSA through the existing Incident Management System. Such requests are processed through the Federal Emergency Management Agency (FEMA) to USGS, which serves as the U.S. representative to UN resources. ◀



A Case Study in Progress

INFORMATION RESILIENCE AND GEOSPATIAL INTELLIGENCE IN NEW YORK CITY

By Alan Leidner, Fund for the City of New York

Seventeen years has passed since the 2001 attack on the World Trade Center, commonly referred to as 9/11. During this time, New York City (NYC) has learned that the ability to use information prior to, during, and following a disaster is a key measure of overall community resilience. The nearly immediate inaccessibility of and eventual loss of information as a result of the 9/11 attacks demonstrated the need to make all aspects of information as resilient as possible. Using

an information-sharing culture, positive action is possible during all phases of disaster management. Information serves as a “force multiplier” whereby the effectiveness of limited resources is greatly magnified by facilitating smarter, faster, and more efficient decisions.

Community resilience is not possible without information resilience. Information resilience is not possible without geospatially-enabled information

and the use of a wide variety of spatial systems—geospatial intelligence (GEOINT). Location is important. Every element entangled in a disaster—citizens, first responders, buildings, infrastructure, equipment, vehicles, and the harm and damage they experience—is tied to a specific location. This makes location a “key field” for all disaster-related databases and a basis for organizing, integrating, visualizing, and analyzing data. Location data allows for more

1. <http://www.un-spider.org/advisory-support/emergency-support/11064/nepal-floods-and-landslides>

effective communication through the distribution of resulting GEOINT products and services to the community.

Lessons learned from post 9/11 disasters, including Hurricanes Katrina, Sandy, and Maria as well as frequent West Coast wildfires, demonstrate that information resilience requires the following elements:

Enterprise GIS: This is the building of shared GIS across all aspects of a community whereby geospatial data created, owned, and managed by constituent sub-organizations and partners creates a comprehensive, shared repository for imagery, streets, structures, elevation, and other foundation layers registered to a common coordinate system.

Operationalization: The adaptation of work procedures which promote routine, everyday use of geospatial technologies across all aspects of an organization builds confidence and familiarity in a manner that enables field workers, managers, and executives to quickly pivot and use adaptations of those applications to support a disaster.

Policy: All organizations concerned with community resilience must agree to work using an integrated, common operating procedure based on openly published and agreed upon common standards.

Comprehensive analysis: The examination and modeling of threats to a community to identify single points of failure, risks of cascading effects, and interdependencies, so that plans can be developed in advance to reduce vulnerabilities, design protections and strategies for public safety, and speed recovery.

Interlocking standards: The building of an interoperative system of centers for information synthesis that creates a series of functional common operating pictures to drive the efforts of each agency with disaster relief responsibilities. Each center must have the ability to exchange information layers with the other centers, including a central operations hub.

Disaster 101: All potentially involved organizations must understand the basic operating functions and tenets of disaster management. This includes the ability to support a variety of search, rescue, and repair operations, giving each team in a disaster zone the information they need, when they need it; and the ability to have each field team operate as a data collection node to help inform incident commanders about real-time conditions.

Practice: The requirement for all organizations potentially involved in disaster response to regularly train together. The first time an incident manager meets a geospatial professional all too often occurs during a response to an actual disaster. This greatly impedes the effectiveness of GEOINT.

Communications and accessibility: The ability of the public to interact with the response community in ways that enable increased awareness of conditions in the disaster zone, helping first responders to maximize their effectiveness in saving lives, reducing injury, and minimizing damage.

Geo-enabled information resilience on this scale does not happen overnight and must be the product of years of building capabilities at all levels of government. The following is an overview of where the City of New York stands in relation to achieving information resilience in the face of future disasters.

The use of geographic information systems (GIS) to respond to disasters in NYC began on the morning of Sept. 11, 2001, following the terrorist attacks on the World Trade Center. The NYC Office of Emergency Management (OEM) quickly recognized that the only way to deal with a disaster on such a vast scale was to collect and organize information spatially. By the afternoon of 9/11, OEM had already established what was to become in subsequent weeks the Emergency Mapping and Data Center (EMDC).

The EMDC did not emerge out of thin air. For the preceding 20 years, NYC had engaged in a process leading to

the development of the city's enterprise GIS. In the 1980s, the Department of City Planning (DCP) developed a geo-coding engine for use in Emergency 911 and many other municipal applications. DCP also developed a street center line map and a parcel map. In 1990, the Department of Environmental Protection began creating a seamless map of the city's 6,000-mile water system. In 1995, work began on creating a photogrammetric base map to which all other maps and geodata could be registered. The integration of these maps was completed just in time for the city to effectively respond to the West Nile Virus epidemic that struck in 2000. Even so, it was believed that the main use of GIS would be for routine municipal operations and its use on a large scale to support disaster operations was not foreseen. The events of 9/11 taught NYC that GIS was the tool of choice to support the voracious information needs of a major response.

At the municipal level, the ability of GIS to fulfill its resilience role rests significantly on the community of GIS users within a jurisdiction. NYC was lucky to have the Geospatial Information Systems and Mapping Organization (GISMO), which was formed in 1990. GISMO, in the years prior to 9/11, continuously brought GIS users together to create a network of enthusiasts who shared knowledge and data. Following the collapse of the World Trade Center buildings and the deaths of more than 2,600 people, the entire GISMO community responded to a request for assistance and made themselves available for service in the EMDC and to other GIS support centers that sprung up in other city agencies. The EMDC, located at the Incident Command Center on Pier 92, also became the place where state and federal GIS responders gravitated, ultimately creating a collaborative GIS community that embraced all levels of government.

GISMO continues to thrive in NYC and now has nearly 400 members and is also part of the larger New York State GIS Association, which is 800 members strong. GISMO has also reached out to form the Coalition of

Geospatial Information and Technology Organizations (COGITO), which includes colleges with GIS programs and other organizations such as the American Geographical Society (AGS). Currently, the NYC GIS community is estimated to number more than 5,000 professionals and students, almost all of whom are networked to each other through the organizations to which they belong.

Following 9/11, the city hired dozens of GIS personnel and became more effective in dealing with emergency events. Hundreds of data layers were built, along with dozens of applications, through the efforts of dozens of city agencies. The water main layer was joined by sewer and transit layers. Many GIS layers were made available to the public through an open portal, greatly increasing the number of people using the city's GIS data and tools. Most recently, the NYC GIS community has collaborated with the Open Geospatial Consortium (OGC) to develop underground infrastructure standards that will help NYC and other municipalities and counties, both nationally and internationally, to integrate critical infrastructure layers. The stage is now set for the final integration of geo-enabled capabilities spanning all levels of government, private and non-profit organizations, community groups, and individual citizens. We only need the enterprise "orgware" (organization-ware) to be drawn together into a collaborative community.

The following steps remain for NYC to achieve a state-of-the-art level of geospatial information resilience:

- The development of interactive mobile applications for first responders and citizens that enable persistent communications based on location to facilitate the most effective possible search and rescue work, and which also allows citizens and first responders to be informed about conditions that directly impact them, wherever they may be located. A variety of crowd sourcing capabilities need to be examined so the most effective options can be identified and deployed.
- The completion of critical data layers including underground utility layers, and their integration based on common standards now being developed by OGC. Soon it will be possible to model the entire built and natural environment.
- The development of artificial intelligence and machine learning techniques that enable the torrent of information flowing into operations centers following disaster onset to be automatically organized, prioritized, and directed to functional centers, first responders in the field, and citizens caught in the disaster area.
- The development of a concept of operations and the systems necessary to govern information exchange during a disaster that allows for the

establishment of multiple versions of a common operating picture for situational awareness, with each version suited to the particular domain requirements of different support functions and agencies.

- The ability of a complex, multi-part system to come together rapidly and operate smoothly under the highest imaginable stress levels depends upon conducting exercises to get all the elements involved familiar with each other, improve coordination and collaboration, and refine methods.

The public is becoming far more sophisticated in its use of GIS tools. Practically everyone has a smartphone, and many users have become adept at map-oriented applications such as those required to navigate, obtain local weather forecasts, and summon car services. Citizens are demanding more of their public officials to sustain their communities during times of disaster. At this point in time, NYC has all the technology and much of the data necessary to achieve complete geoinformation resilience. The remaining challenge is to develop the know-how to bring all the pieces together effectively. This is not an insurmountable task, but one that requires a common understanding of the challenges and the will to meet them. ◀





Photo by Talbot Brooks

Perspectives on Community Resilience from the Developing World

By Talbot Brooks, Delta State University

Most Americans associate international disasters with a massive event resulting in triple-digit body counts, neighborhoods full of smoking ruins and collapsed buildings, and hurried efforts to rush heroic search and rescue teams to a far-off place to free children trapped beneath wreckage for 96 hours. What is not well understood is that Americans both conceptualize and experience emergencies and disasters far differently than those living in the developing world. This is driven, in large part, by vast differences in economic resources, cultural norms, and how these factors are applied to risk tolerance. The application of geospatial intelligence (GEOINT), in light of alternative paradigms derived from how resource-starved communities approach resiliency, provides unique insights that can inform future strategies. Global GEOINT resources fill a niche for these communities, offering immediate and impactful capabilities that can be applied anywhere through international partnerships and volunteerism, and provide easy to understand information by mapping risks and vulnerabilities.

Most disasters are comparatively smaller events such as localized flooding, a strong but brief tornado, a wildland fire affecting a small village, or an earthquake

in a sparsely populated region. These smaller events are far more common, and while loss is still dependent upon the level of exposure and vulnerability of the population, the overall risk is higher due to the relative frequency of events.¹ Communities in developing nations tend to be more cognizant of such higher risk. This is, in part, due to increased vulnerability resulting from a lack of economic resources which, in turn, has a significant effect on the use of built infrastructures and massive investment in response capabilities as the cornerstones for risk reduction plans and overall community resilience. Strategies in such communities tend toward those that promote adaptation and fast recovery instead of investment in mechanisms which harden assets against loss.

Bairro 7-Dzonguene is a small village located near the Manhiça District in Maputo Province, Mozambique. It lies in the flood plain of the Incomati River approximately 20 kilometers inland from the azure waters and pristine beaches of Mozambique's Indian Ocean coast. It is an agricultural community of approximately 200 families and the nearest named place is Chicomela. Water has surged to depths of two meters or more nine times in the past 25 years. In addition to the occurrence

of at least two major tropical cyclones during the same time period, interviews with residents reveal a strong oral history relating the timing, severity, and loss from repeated flooding as the most significant local disaster risk.

Disaster resilience is an active community endeavor and is carefully considered and effective despite a lack of resources available for the construction of levees and flood gauge warning systems and the fact that rescue teams of any means are hours away. The modus operandi or informational response plan, one that has worked effectively at least once, is to float it out. Swimming lessons are available to all residents at no charge and the national disaster management agency, Instituto Nacional de Gestão de Calamidades (INGC), has provided a cache in the form of wooden crates filled with life vests, floating first aid kits, an inflatable rubber boat, a satellite phone, several bullhorns, and other assorted items. Residents have clear plans about where to meet and how to evacuate the area should a flood strike.

The value and effectiveness of these low-tech, common sense approaches cannot be underestimated and have been revisited by emergency managers in the U.S. through the promotion of individual

1. Lavell, A. (2002). Local Level Risk Management. Concepts and Experience in Central America. The Latin American Social Science Faculty and the Network for the social Study of Disaster Prevention in Latin America (LA RED). Presented at the Disaster Preparedness and Mitigation Summit, New Delhi, India.



The security of critical resources such as this community water supply in Mozambique are critical to building resiliency. This well became unavailable during recent flooding, which, in turn, caused cascading failures that led to a cholera outbreak. Disaster managers can improve community resiliency by using GEOINT to assess if critical infrastructure is in a flood zone and then create plans to mitigate that risk. At its core, to have and use GEOINT capabilities is to become more resilient.

response plans, home disaster survival kits, and the emergency financial first aid kit. There is a renewed interest in the U.S. toward empowering individuals to take an active role in aiding their communities, family members, and neighbors during disasters. In parallel, U.S. emergency management officials are also emphasizing the important role government plays in restoring life-sustaining services such as water, power, and transportation to save lives and speed recovery. These actions are based on lessons learned from not just recent events in the U.S., but shared experiences from the developing world.

The aspect most vital to Bairro 7 is the survival of potable water sources for home use and for watering livestock. Inexpensive but sturdy water towers have been erected, and hand-pumped wells are constructed of steel handles and pistons, then mounted atop large concrete pads. It is openly acknowledged and accepted that personal belongings will be lost and homes will suffer damage. Wood homes are gradually being replaced with concrete and brick structures, but their construction is such that they may be quickly cleaned and put back into operation—window glass is rare and roofs are mostly constructed from lightweight, natural materials. The school, clinic, and village records are housed in concrete buildings set atop the highest points in the immediate area and sporting roof-top solar power systems in the event the village's single power line fails.

Adaptation and rapid recovery as the primary means of resilience are not

limited to rural areas. Kathmandu, Nepal, is a city with a population of more than one million. Major earthquakes will cause epic devastation approximately every 50 to 100 years. The 7.8 magnitude quake that struck in April 2015 killed nearly 9,000 people and financial losses incurred were estimated at \$5 to \$10 billion USD—approximately half of the country's gross domestic product.

A review of city resources for emergency response revealed that police carried the primary responsibility for search and rescue, yet lacked any substantial heavy rescue training or equipment. Kathmandu's city fire department has a total of seven fire trucks, though a few additional units may be called from equally limited police resources and the international airport. While piped water service is available throughout the city, there is no hydrant system or similar supply for firefighting. The region is essentially as unprepared today for a future earthquake as it was for the major quakes that occurred in 1934, 1988, and 2015.

The greater perceived risk in Nepal is that of flooding and landslide. It occurs more frequently across a wider swath of terrain than any other disaster type, yet events are seldom national in scope as with an earthquake. The impact of a flood has a more powerful direct effect at the family unit level from both an economic as well as injury and loss of life perspective. Flood waters are fast moving and violent due to the steep terrain, very unlike the flat delta areas of Mozambique. Thus many in Nepal see devastation as a result of an earthquake as inevitable whereas

losses due to flood are perhaps more preventable and easier to recover from.

Resiliency strategies for flooding in Nepal are focused not as much on hardening infrastructure but rather on softening impacts. Flood control structures are largely designed to slow and disperse flows rather than to contain them. Residents have relocated to higher, less-prone ground and undertaken strategies to stabilize slopes through alterations in planting techniques and the use of vegetative cover. As with Mozambique, substantial effort has gone into protecting cultural heritage sites and other community elements that drive the region's tourist economy. Flood research efforts at the International Centre for Integrated Mountain Development (ICIMOD) are focused on the use of remote sensing-based GEOINT techniques to monitor glacial lakes and integrate findings with warning systems.

The attitudes and the resulting efforts occurring in Mozambique and Nepal stand in stark contrast to those of the developed world. Public outrage would rapidly ensue were the Federal Emergency Management Agency (FEMA) in the U.S. to distribute life jackets rather than recommend that the Army Corps of Engineers construct a levee system. The notion of preserving workplace before home is completely alien. Yet in rural America, where help may be far away, financial resources are extremely limited, and smaller-scale disasters more common, there is much to learn from approaches in the developing world.

A small town—whether in the developing world or rural America—that loses a manufacturing facility employing 25% of the population would likely never recover were it to cease operations for more than a few weeks. Families would be unable to pay bills and quickly move away. The loss of the tax base would cause a decline in services followed by the degradation of quality of life, thus furthering a downward spiral from which recovery would be unlikely.

The value of GEOINT, in combination with an exploration of alternative paradigms, permits communities to re-examine how and where they utilize resources. GEOINT is uniquely suited for this role because it may be used to create realistic simulations and accompanying visualizations. Modeling how a community functions under normal circumstances is a key first step to identifying how various population groups, economic systems, structures,

and infrastructure elements interact. The National Science Foundation funded and built The Decision Center for a Desert City (DCDC) at Arizona State University in 2004 for just such a purpose. The driver behind this investment was the desire to further develop the area while maximizing efficient use of water resources and minimizing any accompanying discomfort. Scientists at the DCDC employed GEOINT to do exactly that, using powerful computers to create 3D interactive simulations driven by geographic data to show how the metropolitan Phoenix area functioned biophysically and socioeconomically from a geographic perspective. Urban planners, elected officials, and community members meet at the facility and collectively interact with and alter simulations in an exploration of different scenarios. On paper, some of the proposed solutions might seem too

extreme or dire and would otherwise be rejected without much consideration. This immersive GEOINT approach creates a more tactile experience, and, as a consequence, users may more readily explore, understand, and even select scenarios and solutions previously thought unacceptable.

Communities across the globe may employ similar GEOINT methods for the exploration of community resilience. The lessons learned from the developing world—those that test our conventional thinking with respect to tolerance for loss and investment and explore the interface between low-tech, common sense solutions and advanced, higher-tech solutions—will help drive innovation that can also benefit the developed world. In doing so, new resiliency paradigms and possibilities will emerge through the use of GEOINT and global community resilience will be strengthened. ◀



Conclusion

By Dr. David Alexander, chief geospatial scientist and Flood APEX Program Manager, U.S. Department of Homeland Security, Science & Technology Directorate, First Responders Group; and Talbot Brooks, Delta State University

Collaboration that spans the full gamut of stakeholders and employs spatial technologies as an intelligence activity to identify and strengthen weaknesses in community resilience is the resonant theme for success. Thinking of community resilience as an enterprise-level engagement that transcends governmental departments and civic organizations, community tapestries, and traditional resources provides more effective solutions because they are more encompassing in nature. Many such successful enterprise implementations involve unlikely or distant partners, and future successful collaborations are only limited by the willingness and creativity of potential partners to engage community resilience as a focal point. The true success of community resilience thus resides in embracing and actively engaging strategies rooted in the use of geospatial technologies in this domain.

A resilient response to the future should be forward-looking, not just with respect to resiliency as a topic, but with respect to the potential advances afforded by the advent of new geospatial technologies. Integration of new and emerging geospatial technologies will aid the development of resiliency through improved analytic capabilities. Known future technical trends include:

Applications and telemetry will support next generation first responders to keep them more protected, connected, and secure through geo-enabled textiles, personal protective equipment, personal surveillance devices, and situational awareness capabilities such as UAVs.

GEOINT-enabled tracking devices will facilitate new innovations in logistics, supply chain, and mutual aid that will better speed needed aid to the right place at the right time before, during, and after a disaster.



Initiatives such as smart cities, intelligent transportation, and precision medicine will increasingly rely upon GEOINT-enabled devices to power geo-analytic capabilities that can more rapidly identify disturbances, disruptions, and emerging threats. This information will enable more adaptive response and protective measures that can prevent larger problems.

GEOINT-enabled building materials will become available and be able to detect fragilities as well as to monitor integrity and instability in concert with larger GEOINT sensor and observation systems.

Innovations in risk communication, training, and psychological resilience with GEOINT-enabled gamification, heads-up display, and virtual reality will help individuals, businesses, governments, and communities become more prepared for potential emergencies and disasters.

While such scenarios may seem not only far-fetched, but expensive, the need to employ GEOINT will only grow. The question isn't whether you can afford to implement GEOINT in support of resilient strategies, but rather could your organization and community withstand the costs of *not* doing so?

Additional Resources

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Recommended Courses

R-0387: Analytical Tools for Decision Making, US National Fire Academy. Additional information at <https://apps.usfa.fema.gov/nfacourses/catalog/details/10575>

R-0492: Emergency Resource Deployment Planning, US National Fire Academy. Additional information at <https://apps.usfa.fema.gov/nfacourses/catalog/details/10348>

IS-103 Geospatial Information System Specialist is available from <https://training.fema.gov/is/courseoverview.aspx?code=is-103>

IS-922: Application of GIS for Emergency Management is available from <https://training.fema.gov/is/courseoverview.aspx?code=is-922>

HAZUS-MH courses available through the National Emergency Management Institute at <https://www.fema.gov/hazus-mh-training>

Policy

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