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Mass Fatalities – More Than Just a Number
By Ron Vidal & Catherine L. Feinman

Mass Fatality Incidents & Challenges for First Responders
By Daryl D. Sensenig

Mortuary Logistic Challenges of Mass Fatality Incidents
By O. Shawn Cupp

Physically Uninjured – A Survivor's Perspective
By Lisa Hamp

Planning for the Community vs. Planning for the Plan
By W. Craig Fugate

When Pandemic Management Meets Cybersecurity
By Nitin Natarajan

Plan Big, Even to Respond Small
By Donald (Doc) Lumpkins

Responding to Unique Operating Environments
By Seth Komansky

More content inside from Jerome H. Kahan and Richard M. Ozanich

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Disasters Are About the People

By Catherine L. Feinman

Hurricane Harvey has caused widespread destruction, and its aftermath continues to pose a significant threat to life and safety. In this and other large-scale incidents, the exact number of people affected is hard to determine because of the complex physical and social networks that exist within and between jurisdictional boundaries. Knowing how to manage the lives lost and the lives affected is a challenge. However, when preparing for a catastrophic event, it is important to remember that even one lost life can have devastating effects on a community.

As history has shown, it does not take 500 years for a city like Houston to experience one or more 500-year floods. High-impact, low-probability events can happen at any time. As leaders and news reports talk about this "unprecedented" event, well-informed preparedness professionals understand that planning for these big events is the best way to be prepared for all events. However, a plan will only be effective if it takes into consideration the various factors related to the community where the plan will be implemented.

When many lives are lost, first responders and other preparedness professionals must be adequately equipped and trained to work within unique operating environments. This may include challenges related to mortuary logistics for the lives lost, medical care for those physically injured, or psychological assistance to survivors who are physically uninjured. These unique environments require responders and leaders to be able to apply the plan, but be ready to think outside the box when the plan needs to be adjusted as the incident evolves.

Whether planning for a health crisis like a pandemic, a chemical or biological attack, or some other large-scale natural or human-caused threat, the focus should be on the people: the people who plan and prepare, the people who lead the effort, the people who respond to help, the people who are injured or killed, the people who are otherwise affected. By definition, a disaster is not a disaster if people and their property are not involved. As the massive response effort continues in Texas and the surrounding areas, DomPrep wishes to thank all these people for their efforts and courage during this difficult time.

Mass Fatalities – More Than Just a Number

By Ron Vidal & Catherine L. Feinman

A chemical spill, nuclear attack, biological agent, pandemic, hurricane, and numerous other threats and hazards have the potential to kill enough people to overwhelm any particular jurisdiction. Whether that number is 10 or 10,000 or more, the "unthinkable" can happen anywhere. On 16 June 2017, DomPrep hosted a panel discussion on this topic at the International Hazardous Materials Response Teams Conference in Baltimore, Maryland. The key takeaways from that session are summarized here.

When a disaster strikes, communities must be prepared in advance to manage whatever consequences occur. In a worst-case scenario, this may include mass fatalities. To adequately prepare, communities need to be equipped with the right combination of incident management, personnel, training, and supplies. Valuable assets, which may be available locally or through mutual aid, include, but are not limited to disaster response/recovery teams, crisis and grief counselors, search and cadaver dogs, forensic and storage facilities, and body bags. If the complex mass fatality management process (i.e., recovering, handling, identifying, and reuniting human remains) is introduced during a crisis, then additional public health, mental health, and public relations problems are certain to arise. By understanding such critical information, first responders will be equipped to play a greater role in mitigating the potential cascading life, health, and safety effects to themselves and the public when they are faced with this worst-case scenario.

Meet the Experts

Mass fatality incidents are often in news reports around the world. However, data on such incidents are not clearly defined because the number of fatalities that would overwhelm local resources varies between jurisdictions. A participatory session at the International Hazardous Materials Response Teams Conference hosted by the International Association of Fire Chiefs (IAFC) in Baltimore, Maryland, on 16 June 2017, featured a panel of subject matter experts who presented information and answered questions about the mass fatality response process. Each of the following panelists has been involved in one or more mass fatality incidents:

- The moderator of the discussion, Ron Vidal, is a partner at Blackrock 3 Partners and has served on 12 federal, state, and local task forces. He is a member of the Oakland (California) Fire Safety Task Force, formed by an executive order of Mayor Libby Schaaf, in the wake of the "Ghost Ship" warehouse fire, where 36 people died.
- Daryl Sensenig, MPA, is a faculty member at the University of Maryland's, Maryland Fire and Rescue Institute (MFRI), Special Programs Section and was a member of the recently deactivated National Disaster Medical System's (NDMS) Disaster Mortuary Operational Response Team (DMORT), Weapons of Mass Destruction/All-Hazards unit, within the U.S. Department of Health and Human Services, Assistant Secretary of Preparedness and Response

(*Note:* Effective 31 July 2107, the DMORT-WMD/All Hazards team mission was canceled by the NDMS). He held leadership positions for mass fatality disaster response and recovery efforts during various incidents, including: United Flight 93 crash in Shanksville, Pennsylvania, on 9/11 (40 fatalities); and Hurricane Katrina in 2005 (more than 1,000 fatalities).

- Elias J. Kontanis, Ph.D., is a registered medicolegal death investigator and currently serves as chief of the Transportation Disaster Assistance Division of the National Transportation Safety Board (NTSB). He has participated in victim recovery and identification operations, as well as family assistance operations at more than 40 mass casualty incidents. Three of these incidents were the 2004 Boxing Day Tsunami in Thailand (~230,000 fatalities), the 1999 crash of Egypt Air flight 990 in Rhode Island (217 fatalities), and the 9/11 World Trade Center attacks in New York (2,753 fatalities).
- Paul I. Carden Jr. is the regional disaster officer for The American Red Cross – National Capital Region and director of a Red Cross Divisional Response Management Team. During his 35 years at the Red Cross in volunteer and career positions, he has been involved in or directed the Red Cross Disaster Relief Operations to multiple mass casualty incidents, including: the 1981 Hyatt Regency Skywalk collapse in Kansas City, Missouri (114 fatalities); the Washington Navy Yard shooting in 2013 (12 fatalities); Hudson River mid-air collision in 2009 (9 fatalities); and 9/11 attacks.
- Anthony S. Mangeri, MPA, CPM, CEM, is currently the director of fire and emergency management initiatives and is on the faculty of the American Public University System. He has prepared numerous mass fatality guidance documents and response strategies. He has lectured on the topic of mass casualty and mass fatality operations. He completed a Fellowship in Public Health Emergency Preparedness & Response. He served as operations chief at the New Jersey Emergency Operations Center during the terrorist attacks of 9/11, where he coordinated that state's response to the passenger-aircraft crashes into the World Trade Center in New York City.
- James "Jim" Bruzdzinski is a third generation funeral director and currently serves as the commander of Maryland's only mass fatality team. In this role, he helped write Maryland's Mass Fatality Plan and has responded to incidents such as: a 1987 Amtrak Disaster in Chase, Maryland (16 fatalities); 2005 Hurricane Katrina in Gulf Port, Mississippi (at least 80 fatalities); and a 2004 tanker explosion in Ocean City, Maryland (3 fatalities). Even when the mass fatality team is not needed, it is still called to the scene and ready to deploy whenever multiple fatalities occur.

Multiple people in the audience also had experience in mass fatality incidents, including: the human remains manager for 1,100 decedents of Hurricane Katrina; responder to an aircraft crash resulting in 50 fatalities; and a U.S. Marine battalion commander in Iraq, where an improvised explosive device (IED) killed 39 Iraqi police officers and 49 Marines. With over 200 years of combined experience in the room, it quickly sank in that a mass fatality incident can occur by land, air, or sea and in any city, state, or country around the world.

Define a Mass Fatality Incident

No specific number defines a mass fatality event. It varies between jurisdictions and agencies/organizations depending on the resources and capabilities available when an incident occurs. For example, Sensenig noted that, in addition to the daily workload, a medical examiner can quickly become overwhelmed, especially considering the surge such events would cause on the medicolegal system (e.g., death certificates are required before other services can be provided). Mangeri warned about declaring set limits for mass fatalities, but rather planners should determine risk tolerance through impact analysis such as Threat and Hazard Identification and Risk Assessment (THIRA). Regardless the standards set at the local, state, and federal levels, a community's capabilities vary based on factors such as location and preparedness efforts.

Kontanis offered an alternative approach, stating that "book definitions" that sound good on paper do not necessarily help people think operationally, "I read book definitions and they sounded awesome, up until I was woken up at night and asked, 'Are you going?' Then the book definitions were not very useful. You need operational triggers that are clearly articulated and understood by everyone in your response community." More important than a textbook definition is establishing operational triggers to determine when to implement the mass fatality plan. Instead of a set number of fatalities, the triggers for the plan are: the *potential* for 10 or more fatalities; a complex protracted recovery operation; a chemical, biological, radiological, nuclear, or high-yield explosive (CBRNE) event; or federal agency involvement. The time to implement the plan is shortly after the incident occurs, not when a final victim count is established (e.g., when a building collapses, not after bodies are retrieved).

From a social service perspective, Carden pointed out another factor that is more important than the number: the impact of the decedents on the community. The more connected the decedents were will dictate the level of community disruption, the impact on the community, and the time needed for recovery. Sensenig noted, "You could have a single fatality, but that person is so ingrained in the community that it is a huge loss."

For example, Sensenig mentioned that the threshold number for the state of Virginia is now about 40-50 decedents, yet the Virginia Tech shooting in 2007 resulted in 33 fatalities. The State Office of the Chief Medical Examiner (OCME) mobilized its mass fatality plan, took staff from the regional offices, and went to Roanoke. In about three days, the OCME was able to follow its plan, move resources where needed, address public expectations, and manage the incident without shutting down its other regional offices, thus maintaining continuity of operations throughout the response effort. In contrast to that response, he has witnessed cases where, "When the bell rings, they ignore the plan and try to wing it."

Understand How Fatality Management Has Changed

Once a decedent is retrieved, other concerns are raised about management of the human remains. Knowing how to respectfully handle, identify, process, and reunify the remains with their next of kin are complex actions with serious consequences when not done properly. In some cases, resources that once were available may no longer exist. For example, Mangeri pointed out that hospitals often no longer have morgues because "hospitals cannot charge for decedent management. It's now an operations issue that can be costly to the hospital." Therefore, using hospitals when the medical examiners are overwhelmed may not be an option. This is the type of situation requiring careful planning and asking the right questions in advance.

One positive change in mass fatalities that Kontanis has noticed over the years is "a shift in concept from numbers and 'mass' [mass fatality] to thinking about 'complexity' [complex incident fatality management]." Contaminated remains – for example, one dead person infected with Ebola – present a complex fatality. With the federal government and media converging on the location, such incidents present additional complexities related to families, first responders, transportation, and so on. In addition to those killed during the incident, cemeteries containing hundreds or thousands of previously deceased remains can also pose recovery management concerns as caskets become displaced.

Another complexity for mass fatality incidents involves fragmented remains. Sensenig shared the example of a 30-person commuter jet crash. Thirty people may be within the jurisdiction's threshold, but the complexity of the fragmented remains (e.g., retrieving and identifying bone samples) may affect the mission. Forensic science such as DNA testing can facilitate the process, but can add further complexities as well. In Shanksville, Pennsylvania, on 9/11, he noted, DNA analysis was conducted, whereas DNA testing was not performed following Hurricane Katrina. The disparity was caused by fiscal accountability and arguments over who would pay for the testing.

Families of the decedents present another complexity. Sensenig noted concerns that victim assistance teams encounter when talking to the families about remains, "We've identified your loved one (and it's an amount that fits in a shoebox)." Complicating an already sensitive situation includes determining what to do if more remains are identified later in the process.

Manage Surge During Complex Events

With all the complexities involved in a mass fatality incident, managing the surge requires extensive planning. Bruzdzinski described how Maryland's surge capacity has grown and expanded over time by building dual-use facilities, "It has really changed, and for the good." For example, a new morgue for the state of Maryland has "a phenomenal autopsy suite" that is used every day and another that is used for surge. The parking garage is designed to convert into a disaster morgue within about an hour with a capacity for about 100 decedents. The garage is equipped with hot and cold water lines, drains in the floor, electrical outlets, and a garage with body boards.

To effectively plan for mass fatality incidents, it is important to remember that mass fatalities coincide with mass casualties, which means that family services, emergency medical services, law enforcement, and other response agencies may not be available. "Know that, during these watershed events, contingency systems may be overwhelmed as

well – medicolegal systems for fatality management, and care and management systems for both the injured and their families," said Mangeri.

Many steps occur before fatality management begins. For example, at the triage level, transport resources cannot be applied to decedent management until all living transports have been made. This means being able to identify not only when the event begins, but also when the event ends, and what the jurisdiction's ability is to respond to other incidents that happen during that period.

Even on a day-to-day basis, highly infectious diseases result in a percentage of decedents, which should be a public health wakeup call. On an emergency response call – hazardous material, law enforcement, and emergency medical – fatality events may unfold throughout the response. Complex incidents require a better understanding of how to surge for an event and continue to operate for the next event for unknown durations. As complexity increases, political and budgetary realities also set in.

At the NTSB, a federal agency with approximately 420 employees across the United States, Kontanis emphasized the whole community response concept following a mass casualty incident, "What works really well is the concept of collaboration in a complex fatality management event. Fostering collaboration and setting aside egos is what NTSB embraces." Enhancing, rather than impeding, each others' abilities to do their work was demonstrated in the NTSB's response to flight 3407 – an aircraft that crashed in Buffalo, New York, on 12 February 2009, resulting in 50 passenger, crew, and ground fatalities.

The NTSB is responsible for facilitating victim recovery and identification following air carrier accidents that occur in the United States resulting in a major loss of life. The agency accomplishes this objective by conducting a gap analysis with the medical examiner or coroner early in the response and activating pre-established memoranda of agreement with various federal agencies to support the victim recovery and identification process. Following the Buffalo accident, the NTSB at the request of the Erie County Medical Examiner's Office activated the Armed Forces Medical Examiner System, Department of Health and Human Services – DMORT, and FBI Evidence Response Team and Disaster Squad to support the medicolegal process. In addition to these federal forensic assets, a total of 68 federal, state, and local agencies, and nongovernmental organizations responded to this accident.

Enhance Personnel & Process Resilience

It is important to note that the state must engage DMORT (under ESF-8) early because it may take 36 hours for the team to get to the scene and become fully operational in a deployable morgue. In the meantime, other response teams could suffer from burnout and need to be managed effectively to minimize the physical and psychological effects that may compound as the hours pass. Because mutual aid is often required in mass fatality incidents, the use of standard triage tags that are regionally recognized can facilitate operations.

Media and cameras are common during complex incidents, so media management is a big part of large-scale incidents. In addition to media, mass care operations are also a standard part of each mass fatality situation. Mangeri pointed out that there is typically 5-10 family members, friends, colleagues, etc. that show up for each decedent. As such, they must be planned for as well. Transportation events and areas with large transient populations increase

the chance that loved ones will be coming from other areas and may require additional sheltering and care resources. This highlights the need to know the population being served (e.g., languages spoken) and the services being provided:

- Hospitals and emergency medical services care for the injured, ill, and infirmed;
- Mortuary, funeral, and medical examiner/coroner services care for decedents;

The Incident Management System provides consistency across all hazards, but jurisdiction over the incident is situational to where the event occurs and who has authority to make decisions (e.g., state or county government, commonwealth). This can be complicated more by the timing of the event. As such, agencies and organizations must determine the rules during "peacetime," so they are more prepared for "wartime" – when seconds count. By mapping relationships and conducting drills and exercises with key stakeholders – including the medical examiner/coroner – during peacetime, responders save critical time during the incident.

Bruzdzinski warned that the medical examiner/coroner car often does not have a radio to communicate with incident command like the law enforcement, emergency management, and emergency medical services do. As such, they may not know what is going on and may not even have access to the triage tent to begin necessary operations with regard to those killed during the incident. Plans should include a liaison to ensure that the medical examiner/coroner have the access they need to fulfill their roles and responsibilities. Drills can help identify these and other gaps as well as overlaps, which can lead to delays as agencies determine who is responsible for various tasks.

Carden recommended bringing a lawyer in either during or following the exercises because of the complexities involved in mass fatality incidents. Some things an agency may normally do, may not be permitted or acceptable when managing fatalities – for example, a death certificate may be needed before moving any bodies – and some regulations may need to be established in advance. In addition, some decisions cannot be made until jurisdiction is established.

Jurisdiction includes determining which doctor signs the death certificate. Mangeri noted that a past TOPOFF (a national level exercise with top officials) revealed this question is not always easy to answer. For example, if a person dies in the field and is brought to the hospital emergency room, the doctors may not like to sign the death certificates if they were not present when they passed. The more fatalities involved, the more complicated the situation becomes and the more critical it is to have an established flow path.

This goes beyond the legality of the situation to a legally recordable event. Firefighters, for example, are familiar with the process of respond, deploy, and back in service, but that does not work in a mass fatality scenario. If not planned, there will be an adverse effect on service continuity because of the need to dedicate services for the duration of the event. A planning matrix should include: local conditions, contact lists, relationships, as well as gaps and overlaps in resources and agency roles. With so much time being devoted to taking care of decedents, the next concern to tackle is what to do about the people who are still alive and still on scene, "How do we get our people back?"

Address Psychological Well-Being of Responders

Carden described the American Red Cross's desire to prequalify people before sending them into the field – for example, knowing the level of knowledge, skills, and abilities of each person. This includes whether they have witnessed a death before. Although not fully implemented yet for knowing all deployable resource capabilities, the Red Cross is working toward that goal. Other response agencies may also prequalify personnel before deploying them to high-stress incidents. Self-selection and looking out for each other play large roles as well – for example, opportunities for social interaction at the end of each day to determine how teams are coping with the response and improve camaraderie. Engagement makes a difference for psychological wellbeing.

The psychological status of responders is an area that is receiving an increasing amount of attention, which panelists agreed is a "good thing." Although Kontanis is "not a fan of mandatory debriefing sessions after an event," he said that, "What does work is cohesiveness, which is built on open communication." He clarified that this communication needs to be with somebody on the team who that person can confide in and trust, as well as a support network outside of work – both built on open lines of communication. As a leader, he encourages his team members to feel comfortable voicing their limits without fear of punitive repercussions. He stresses to his team that, if they do not take care of themselves, then they cannot take care of others, and, "If we can't take care of others, then we won't meet our mission objectives." Mangeri agreed, "You are a long-term asset at the scene. Know when to put yourself out of service."

Unlike the fire and other large-scale response services, the funeral industry is more isolated, without the same level of camaraderie. Bruzdzinski, recalled his response to Hurricane Katrina, where his 12-person team "infiltrated" funeral homes – that is, took over operations when locals were not able to fully manage the adverse conditions. Similar to the fire service, the culture of funeral directors is not conducive to asking, "How do you feel?" However, he noted the significant benefit of his team gathering around a campfire at the end of each day to just ask, "What did you do today?"

Key Takeaways & Recommendations

Everyone is part of a "tribe" – hazmat, funeral directors, firefighters, emergency medical, public health, emergency management – but all must work across jurisdictions and agencies when a mass fatality incident occurs. Perhaps the biggest challenge for mass fatalities is managing expectations:

- *Time expectations:* When people expect that forensic science takes only 20 minutes (i.e., "CSI" effect). Accuracy is more important than speed, especially in situations where the wrong decedents' remains could be given to families.
- *Recovery expectations:* When people expect recovery to occur rapidly. However, entire buildings may need to be rebuilt as bodies continue to be identified. In New York City, remains recovered from the scene are still being identified more than 15 years after 9/11.
- *Process expectations:* When people expect fewer steps in the process. A large building fire, for example, beyond putting out the fire and recovering bodies involves post-event fire investigations, changes in building codes, etc.

The panelists closed the discussion by describing what keeps them up at night when considering mass fatality incidents. Self-care was the prevailing response:

- Acknowledge what needs to be done, but understand that sleep is needed.
- Ensure the safety and well being of all team members.
- Form an operational perspective to address expectations of society and align these expectations with the reality of the situation.
- Do not make promises that cannot be kept ("We are not going to stop until we find your loved ones," may not be feasible).
- Protect the scene and do not take pictures of anything that could compromise the response or recovery efforts.
- Build capacity and resilience to ensure that people are equipped with the right strategy and resources to implement the system.
- Counter statements such as, "It will never happen here," "It's not my job," and "I got this," with realistic expectations, education, and trainings.

Complex fatality management requires a multidisciplinary, multijurisdictional response. However, perhaps the biggest difference between fatality management and other disaster management efforts is that not all the key stakeholders and processes are known in advance and integrated into the response. By building relationships with medical examiners, coroners, and other fatality management personnel, other response agencies will better understand and facilitate the process of managing decedents – from moment of impact to reunification of remains with their loved ones.

Ron Vidal's (pictured) corporate career spans 35 years as a senior executive in critical infrastructure including fiber optic networks (metro/long haul/subsea), data centers, oil and gas, power systems, and capital markets. Previously, he was a senior executive at Level 3 Communication, UUNet Technologies, MFS Communications, and Kiewit Construction. He led Level 3 Communications relief and recovery efforts in New York City after the 9/11 World Trade Center terrorist attack. He also served on Mayor Dinkins New York City Task Force on Network Reliability and currently serves on the California Cybersecurity Task Force. He has advocated technology public policy to members and staff of United States Congress, commissioners and staff of the Federal Communications Commission, and Commissioners and staff of the California, Illinois, Massachusetts, and New York Public Utility Commissions, notably testifying before the House Subcommittee on Telecommunications and the Internet on E-911 and Voice over Internet Protocol policy. He is a volunteer firefighter, and former chair of the Emergency Preparedness Commission in Mill Valley, California, and a technical peer reviewer for the Federal Emergency Management Agency's Assistance for Firefighter Grant (AFG) program.

Catherine L. Feinman, M.A., joined Team DomPrep in January 2010. She has 30 years of publishing experience and currently serves as editor-in-chief of the DomPrep Journal, www.DomesticPreparedness.com, and the DPJ Weekly Brief, and works with writers and other contributors to build and create new content that is relevant to the emergency preparedness, response, and resilience communities. She also volunteers as an emergency medical technician, firefighter, and member of the Media Advisory Panel of EMP SIG (InfraGard National Members Alliance's Electro-Magnetic Pulse Special Interest Group). She received a bachelor's degree in international business from University of Maryland, College Park, and a master's degree in emergency and disaster management from American Military University.

Mass Fatality Incidents & Challenges for First Responders

By Daryl D. Sensenig

Mass fatality incidents present many challenges. To effectively plan for such events, certain key factors must be taken into consideration: common causes and challenges, as well as resources available. By communicating with the local medical examiner/coroner, being familiar with mass fatality plans, and learning about any pertinent capabilities and limitations, emergency planners can make informed decisions and close existing gaps.

A mass fatality incident (MFI) is essentially a surge issue. Just as a mass casualty incident is a surge on the emergency medical transportation and trauma care systems, an MFI is a surge of the medical-legal system in the authority having jurisdiction (AHJ). The medical-legal system is the system within the AHJ that is responsible for determination of the cause and manner of death and the identification of unknown decedents and the issuance of a death certificate document.

For planning purposes, some first responder organizations define an MFI by the number of victims – for example, three times the normal caseload for the AHJ within 24 hours of the event. The problem with setting a minimum number is that it does not take into consideration the level of available response capabilities or the condition of the remains. Twenty fatalities caused by a single incident could be overwhelming for a small community, but a larger medical-legal system would find those numbers well within their capabilities. A more practical approach to consider is to ask:

- What is the maximum number of the deceased that the local system can handle, taking into consideration that fragmented or contaminated remains may complicate the problem?
- Then, what plans and exercises should be developed to reflect the reality of local resources, and how would they need to be augmented?

Common Causes of & Challenges Related to an MFI

The most common causes of an MFI are: transportation (air, rail, motor coach, marine vessels) accidents, structure fires or collapses, floods, hazardous materials releases, and mass homicides. These events are often the results of earthquakes, tsunamis, hurricanes, tornadoes, and criminal (terrorism included) acts. Pandemic illness can factor into this, though pandemics generally are not acute situations and are often regional events and may develop over time. Pandemics can impose a sustained "surge" on the AHJ that lowers the threshold for becoming overwhelmed. In some jurisdictions, the opioid epidemic is having this effect.

First responders face six challenges when dealing with an MFI. The first challenge is the "It won't happen here" or "It's not my job" challenge. In some planning models or threat analysis programs, an MFI is a low- to medium-probability event, and then only if there is a target hazard such as an airport in the jurisdiction. That being the case, the "It will not happen here mindset" kicks in and there is little to no attention paid to MFI planning or budgeting or inclusion of the medical examiner/coroner in drills and exercises. It would be wise to take a closer look at MFI probability factors. If major highways or rail lines are within the community, the risk of an incident that causes many fatalities is real. If tornadoes or earthquakes threaten the area, the potential for an MFI may be significant, and any town can experience mass fatalities from a shooter with automatic weapons and a desire to kill.

From "It won't happen here" to "We got this," first responders face these and other challenges during mass fatality incidents.

Second, the resolution of MFIs will last for days, weeks, or more. Prepare for a multi-operational period event. If the event includes an extended recovery of the remains – like the Oklahoma City bombing in 1995 or the World Trade Center in 2001 – the process will take several days or weeks. If the remains are less than intact, as often is the case with aircraft accidents or explosions, the collection and processing of the fragments will take a lot of time. The remains could be contaminated with a hydrocarbon, toxic industrial chemical, or chemical-warfare agent. Clearly, there will be a need for a significant command post and resources to support a logistically intense operation. If the event is a crime scene, like the Pulse Nightclub (Orlando, Florida), expect a major law enforcement presence and that bodies will not be moved until law enforcement is finished with the investigation. That process could take days.

Any major incident that involves a large number of government agencies, medical facilities, and other community resources requires a management system that can address: the multi-agency, multi-jurisdictional operations; the planning, logistical, and administrational issues; and the tracking costs. A system is needed that can expand and sustain itself for weeks and address public information, safety, and liaison needs. The obvious solution is Incident Command System, and the fire service is often the only local agency that can think of sustaining operations for days or weeks. The fire department's role may evolve as the incident moves from response to recovery to identification. The role of the fire department may be to provide the functions of an "overhead team." Similar to the U.S. Forest Service, the fire department's role would be to assist in the development and publication of the Incident Action Plan.

Media coverage is the third challenge. There must be a plan to manage media response – a designated area for the media, with controls on unwanted or illegal intrusions that are enforced by the police, especially at and around the scene and near the families of the victims. A joint-information center/process/plan is a must.

Fourth, the expectations of the deceased loved ones or Next of Kin (NoK) can be challenging:

- What will the families or the NoK be told about the process of identifying and releasing the remains?
- Where do the families go to receive timely accurate information regarding their loved ones?
- Once the deceased is legally identified, what is the process and structure for notifying the NoK? The medical examiner and often law enforcement handle this step, but it is important that all first responders are aware of who is responsible for this task.

Few people outside the forensic community understand what is involved in the accurate, positive identification of the deceased, why it needs to be done a certain way, and that the process takes time. Distraught family members may agonize through the hours between the incident and the final confirmation of the loved one's death. There are expectations that the accurate, positive identification of the deceased can occur within an hour. This misconception is reinforced by the entertainment industry with forensic-based television programs and movies. In these programs and films, family members are routinely shown the bodies to visually verify their identities. These expectations are neither realistic nor are they considered to be scientifically appropriate methods for positive, legal identification. Identifications need to be properly done and done only once. That will take time. If DNA collection of ante mortem evidence is needed, then the process of collecting and analyzing the evidence can be time consuming and requires communications with NoK.

It is essential to develop and test a plan for standing up a family assistance or victim assistance center. A single, centralized location for the release of official information and privacy for the NoK can be accomplished on the terms that they are compassionate, respectful of privacy, and timely. The example in Oklahoma City in 1995 after the Murrah Building bombing is considered a model for this type of center. A large church in the downtown area was used as a center because it was an easily located landmark. Ample parking was available and a commercial-grade kitchen was on-site. There were private rooms for notification and grief counseling out of sight of the public. One element not present was overnight lodging accommodations, as this was primarily a local event. In an event where families may be traveling some distance, considerations for lodging have to be included. There is much more information available at the U.S. Department of Justice's Office for Victims of Crime website. The National Transportation Safety Board (NTSB) also has resources available through the Aviation Disaster Family Assistance Act of 1996.

The fifth challenge is determining which specialists might be needed to augment local capabilities and to mobilize those resources. Conversely, first responders need to have a plan to deal with the likelihood of unneeded, or self-dispatched responders driven by curiosity or a desire to be at "the big one." MFIs related to disasters and other high-visibility events have often brought out many unrequested, self-dispatched responders who can cause significant problems for the jurisdiction already strained by the event. These responders can be in a

variety of disciplines, such as forensic canine (K-9) handlers, mental health providers, and off-duty first responders from other jurisdictions. There should also be a policy on unrequested responders in disaster plans.

A final challenge is the "We got this" syndrome, which is when authorities resist reaching for assistance. This challenge is not limited to public safety; the medical examiner/coroner is not immune to this syndrome. An exercise that focuses on an MFI with complicating circumstances is one of the best ways to demonstrate when/where a community can be overwhelmed. If mutual aid is needed, then make sure these resources are included in a mutual aid plan and that the plan is up to date and has been exercised. If assistance is requested, ascertain the logistical and support needs of the resources and the estimated time of arrival as well as the length of time the resource can provide assistance.

Several items have been mentioned in this article, specifically, the need for an overall MFI response and recovery plan as well as a media/communications plan, a family assistance plan and a mutual/aid assistance plan. Many communities today are training and exercising for an "active shooter" event. However, in the design of the exercises and training, do not stop when the last Basic Life Support unit leaves the scene. Instead, start the second phase or next exercise with the scenario that all of the living have been transported or treated: law enforcement has completed their investigation and is now providing perimeter security. Then consider what is next.

Available Mortuary Resources

There are various types of assistance available to local agencies, private sector groups, and state and federal level response teams. Funeral directors associations have response capabilities that can assist the AHJ with management and release of remains. These teams can respond in less than 24 hours and provide assistance with handling bodies and communications with the NoK. Funeral directors associations may not be able to provide assistance in the forensic part of the process, as they do not have the expertise or equipment to do so.

Florida and Michigan, for example, have state-level teams that can assist with victim identification. These teams are sometimes partnerships between the state and universities that have forensic science programs. Like funeral directors associations teams, state teams can respond quickly, generally in less than 24 hours. Some of these teams have equipment

that can support or supplement the AHJ with morgue operations. A limitation of the state teams as well as the funeral directors associations is the length of time they are available to assist in the identification process. Many of the providers on these teams have limits on how long they can be away from their primary place of employment. However, for smaller numbers of decedents, a state-level team may be the appropriate resource.

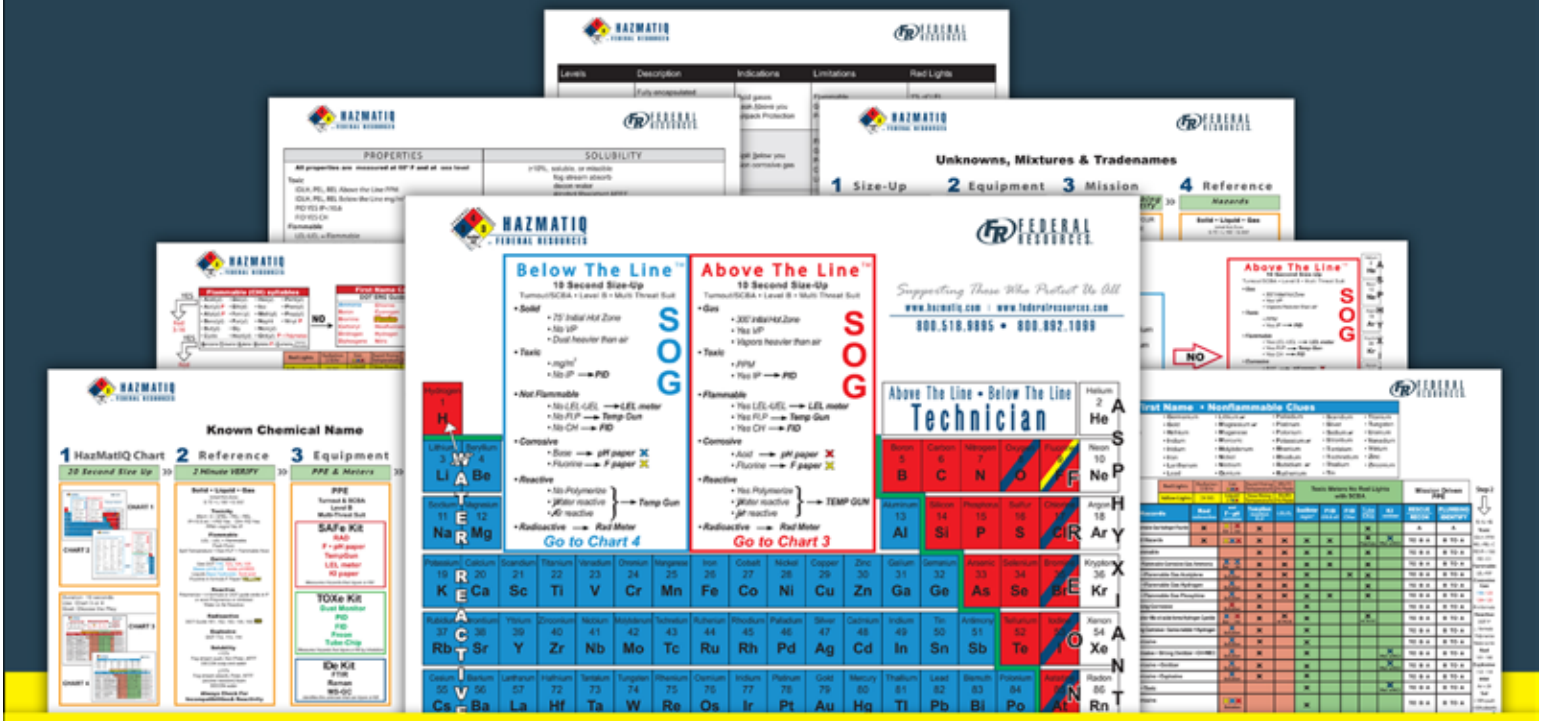
Federal assistance is available through the Department of Health and Human Services, National Disaster Medical System (NDMS). NDMS has a Disaster Mortuary Operational Response Teams (DMORT) in each FEMA region and two national teams. These teams are staffed with specialists that become temporary federal employees for the duration of their deployments. These teams can provide two-week rotations that can continue for several months as needed. This was the case in New York after 9/11 and in Louisiana after Hurricane Katrina.

DMORT has three deployable morgue units that are strategically located throughout the country. These units can be delivered by trucks and generally set up in less than 72 hours in the continental United States. One of the national teams (Victim Assistance) can be brought in to assist with the family/victim assistance functions, while the other national team (DMORT-WMD/All-Hazards) can decontaminate the remains. To request these teams, local government asks the state for assistance, which, in turn, requests federal help under Emergency Support Function #8 (ESF-8).

In preparation for an event with mass fatalities, become familiar with the local or state medical examiner/coroner. Become familiar with their plans or plans of the agency (often state or local emergency management) that address fatality incidents. Learn the capabilities and limitations of their staff, their facilities, and their equipment. By doing so, informed decisions can be made regarding the gaps between the "surge" from the incident and capabilities of the medical-legal system.

Note: Since this article was first drafted, the National Disaster Medical System, as part of a larger reorganization and re-alignment of resources, has "terminated" the mission of the DMORT-WMD All/Hazards team. Emergency planners should review their MFI plans to determine if this change has an effect on their plans and expectations of federal assistance via ESF-8.

Daryl Sensenig is a retired battalion chief from the Anne Arundel County (Maryland) Fire Department (AACO FD). Since 1998, he has been a member of the National Disaster Medical System's Disaster Mortuary Operational Response Team (DMORT), and a former member of the Weapons of Mass Destruction/All-Hazards unit, within the U.S. Department of Health and Human Services, Assistant Secretary of Preparedness and Response. He has an in-depth knowledge of fatality response from several leadership positions for mass fatality disaster response and recovery efforts, including United Flight 93 on 9/11 and Hurricane Katrina. He has served as a hazardous materials team member and commander, the operations officer for the Emergency Management Bureau, of the AACO FD. During the Deepwater Horizon Oil Spill in 2010, he accepted deployment to serve on the Incident Management Team in Louisiana as a deputy operations section chief. Currently, he is a faculty member at the University of Maryland's, Maryland Fire and Rescue Institute (MFRI), Special Programs Section.



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Physically Uninjured – A Survivor's Perspective

by Lisa Hamp

On 16 April 2007, I headed to computer science class in Norris Hall at Virginia Tech. Fifteen minutes of computer science class remained when there was an extremely loud popping sound. I had rarely, if ever, heard live gunfire. I froze. Thankfully, the teaching assistant and classmates took action. They stepped into the hallway, exploring the unusual sound, when the shooter came out of a classroom across the hall. They called 9-1-1, built a barricade with a card table and desks, and kept the shooter out of the classroom, just seconds before he attempted to enter. There was no lock on the door. Classmates suggested lying on the floor because the gunman was shooting chest-height.

The Norris Hall shooting lasted 12 minutes. Within hours of the last gunshot, the university was instantly overwhelmed by media, overwhelmed with people and organizations who want to help and donate, and overwhelmed with personal emotions and really hard questions: How did this happen? Why at our school? What do we do now?

My classmates and I walked out of Norris Hall physically unharmed. After the shooting, I constantly compared myself to the physically injured survivors, and thought I was undeserving of being recognized as a "survivor" because the shooter had not entered our classroom. Therefore, I thought I needed to be quiet and minimize the impact the shooting had on me. Staying as busy as possible, I needed help, but did not realize it. Not knowing how to deal with post-traumatic stress, I used food and exercise to cope. Eight years after the shooting, I sought counseling for an eating disorder.

What to Do Now

Naturally, university staff members start with what they can see – the families who lost their daughters and sons and the physically injured survivors in the hospital. They organize private events for those deeply affected and public events for the larger community. By having private events, universities

create safe places for those whose lives and families are changed forever. But the key questions are: Who should be invited to the private events? Who qualifies as "lives changed forever"?

It is not as if a line can be drawn with people on this side of the line being deeply affected and people on the other side not affected. I was on the side of that line that was not invited to the private events and received the same invitations to the public events as the rest of the students and faculty. Yes, there were people deeply affected and, yes, there were people less affected. However, there is no clear line between the two.

It is extremely awkward and uncomfortable to ask for resources and invitations to attend private events when students and faculty died, and others may not be able to walk again. It feels selfish. However, I learned many things from counseling, two of which are: to make self-care a priority; and to not compare one experience to anyone else's. The unseen is often forgotten and, to be honest, I felt forgotten. My scars are invisible, but it does not take a bullet wound to be injured. The psychological effect of surviving an active shooter event is intangible and boundless. The level of trauma that each individual experiences varies.

Life Recently

In 2015, I recovered from my eating disorder. In 2016, my husband and I started our family, and I gave birth to a baby girl. I often reflect on the years between the shooting and recovery, and have come to know them as the lost years after trauma. I remind myself to keep self-care a priority. Life is a journey and lessons are learned on the way. Hopefully, this story will help other schools, agencies, and organizations learn from my experience, and recognize the need to provide adequate support, resources, and recognition for physically uninjured survivors in the future.

Lisa Hamp is a survivor of the 2007 Virginia Tech shooting in Norris Hall. She shares her story to raise awareness about the delayed effects of trauma. Her work focuses on tangible ways to make schools safer, as well as improve schools' recovery plans when tragedy does strike. She believes that injuries from trauma can be both physical and mental. She has a bachelor's degree in mathematics from Virginia Tech, a master's degree in operations research from George Mason University, and a master's degree in economics from John Hopkins University. Learn more about Lisa at lisahamp.com.

Mortuary Logistic Challenges of Mass Fatality Incidents

By O. Shawn Cupp

Today in the United States, some in society are hesitant to acknowledge or plan for "failure options" – in other words, admit that the worst of the worst can happen. The military requires planning for just about every situation including when operations do not go as planned. However, those in emergency management and domestic preparedness operations need to consider tragedy and events unimaginable to most people.

One "unimaginable" event that preparedness professionals must anticipate is a mass fatality incident on a regional or national level. Preparing for this type of event requires understanding the complex problem, ensuring adequate logistic resources, and detailed planning for this kind of incident. All three of these areas require careful and well thought out consideration.

The Complex Problem

The United States continues to improve preparedness efforts for a number of possible manmade and natural disasters. These improvements have occurred most notably since the 9/11 terrorist attacks in 2001 and Hurricane Katrina in 2005. Planners at the local, state, tribal, and federal levels continue to improve their plans and details of their responses to a number of likely events.

Nevertheless, the United States has little experience with a mass fatality incident on a national scale. The attacks of 9/11 and Hurricane Katrina were tragic but were not on the scale or scope of the 1918-1919 Spanish Flu pandemic, when a quarter of the U.S. population fell ill and more than 675,000 Americans died. Outside the United States, the 2004 Tsunami in South-East Asia and the 2011 earthquake, tsunami, and subsequent Fukushima Daiichi nuclear reactor failure are in the large-scale mass fatality incidents category, with numbers of deaths estimated close to 300,000 and 20,000, respectively. The need to recognize and strengthen fatality management, planning, and response are critical to recovery efforts during a mass fatality incident.

Regardless of the size of the mass fatality incident, the medical examiner/coroner (ME/C) is the legal authority to conduct victim identification (or augment the lead investigative agencies to complete victim identification). The ME/C determines the cause and manner of death and manages death certification. The ME/C is also responsible for other medico-legal activities such as notification of next of kin. The number of deceased is a significant driver in the amount and type of resources needed to search, recover, and identify decedents. In general, the higher the number of fatalities, the more resources required for managing and processing the remains. Understanding this requirement involves planners recognizing the need for greater numbers of adequately trained people to effectively manage a mass fatality incident.

Culturally, death in the United States is often considered a taboo topic. However, in 2014, the Centers for Disease Control and Prevention (CDC) estimated 2.6 million deaths in the United States. Most of these deaths are anticipated and processed through normal funeral home channels. However, of these 2.6 million reported deaths, there were 135,928 accidental and 42,826 suicide deaths. The total number of U.S. deaths recorded each year by the CDC ranged from 2,148,463 in 1990 to 2,626,418 in 2014. Therefore, this information provides a predictable number for funeral homes and services to process and plan for on an annual basis.

In addition, the number of caskets and cremations required each year are highly dependent on just-in-time logistics. Caskets and coffins are not stockpiled in large warehouses. Using "lean Six Sigma" business practices, materials to produce caskets are ordered, built, and delivered for just-in-time requirements. Based on material requirements that have been steady for almost 25 years, the U.S. funeral industry provides goods and services to citizens established on historical demands. This keeps costs down and provides a multitude of options for consumers. However, these options are costly, whereas throughput is the primary consideration during a mass fatality incident.

Decedent Remains Planning & Educational Resources

In response to a mass fatality/incident, planning for decedent management – which includes resources and mortuary options – is required. Options available for human remains in a mass fatality incident require prior planning (see Table 1). Ranging from caskets and cremation to more innovative approaches like biodegradable alternatives, each option should be considered for use in a mass fatality incident. The following recommendations would help mitigate the logistical impact of mortuary disaster operations:

- Integrate planning for mass fatality incidents into planning exercise considerations and execute mortuary operations during exercises.
- Participate in national mass casualty exercises like the U.S. Northern Command (NORTHCOM) Chemical, Biological, Radiological, and Nuclear (CBRN) Response Command Post Exercise, "Vibrant Response."
- Explore plans that various hospitals, states, and regions have developed in response to mass fatality incidents. Each local, state, and tribal area is different, but planning for mass fatality incidents requires significant time and details to meet the demands of such an event.
- Vet options beyond caskets to mitigate the psychological impacts of a mass fatality incident.

Further Recommendations

A mass fatality incident is a crisis that no emergency planner would want to endure, but the likelihood of such an event does exist. The complexity and related logistical concerns require more consideration as highlighted by incidents that have occurred in various parts of the world. Planning at the regional and national levels, during exercises, would provide leaders with a better understanding of this multifaceted problem.

Table 1. Possible Options for Mortuary Operations

Options	Logistics considerations	Cost	Ease of use in domestic preparations
Casket	Materials, order times, number available	Relatively high	Acceptable means
Cremation	Crematorium facilities	Relatively high	Acceptable means
Remains Pouches	Requires prior planning	Relatively inexepensive	Less than acceptable except in emegencies
Freeze Dried	Still new option with limited facilities	Relatively high	Probably not a feasible option
Biodegradable	Newer option with limited facilites	Relatively high	Not standart practice or accepted across population

In addition to the hyperlinked websites throughout this article, additional educational resources on the topic of mass fatality incidents include:

- *"Mass Fatality and Casualty Incidents: A Field Guide," by Robert A. Jensen (1999)*
- *"Mass Casualty and High Impact Incidents: An Operations Guide," by Henry T. Christen (2002)*
- *"Mass Fatalities: Managing the Community Response," by Peter R. Teahen (2011)*
- *"Mass Fatality Management Concise Field Guide," by Mary H. Dudley (2013)*
- *"Army Techniques Publication (ATP) 4-46, Contingency Fatality Operations" (2014)*

Disclaimer: The views and conclusions expressed in the context of this document do not reflect the official position of the U.S. Government, Department of Defense, United States Department of the Army, or the U.S. Army Command and General Staff College. The author has no conflict of interest, including direct or indirect financial interest that is included in the materials contained or related to the subject matter of this manuscript.

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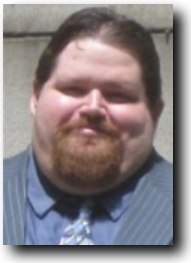
Plan Big, Even to Respond Small

By Donald (Doc) Lumpkins

In emergency planning efforts, there is much debate about whether to plan for the worst and scale down, or plan for current threats and scale up. Of course, in complex systems, small changes in initial conditions can have profound effects. By considering larger, low-frequency events, communities can overcome this challenge and be better prepared for disasters of all sizes.



In certain areas of life, it is normal to start big and end small. Tailoring begins with large sheets of fabric that are cut, sewn, and fitted to make the perfect suit. Stones are chiseled down to form a sculpture. Yet, in some corners of the emergency management community, there is continued debate about the direction of scalability: prepare for large-scale, catastrophic events and scale down to deal with smaller incidents; or plan around more probable events and rely on the inherent flexibility of the response system to scale up.

Budgets, time constraints, and a variety of other contributing factors have caused many in emergency management to focus on the threats and hazards that are most likely to occur. As a result, some in the field forego consideration of catastrophic events that would lead to mass casualty incidents. Preparing for these large-scale events, however, provides the best forum for a truthful consideration of a community's capabilities and needs.

The Doctrine Case

Modern doctrine points to the need for scalability in community planning and operations. One of the defining characteristics of the National Incident Management System is that operations should be scalable, providing the ability to deal with not only day-to-day incidents but also large-scale events. Comprehensive Preparedness Guide 101 recommends flexible planning that can address traditional and catastrophic incidents. The National Preparedness Goal has as one of its key drivers the need to consider cascading events in order to fully understand the potential hazards facing a community. Each piece of doctrine was developed after engaging stakeholders from across the nation – experts in emergency management and homeland security. Despite the recommendations of colleagues to consider these mass casualty events, there is still debate within the field.

Applying the Chaos Argument to Operations

Considering chaos theory in mass casualty planning helps paint a clearer picture as to why it is better to think big and scale down instead of thinking routine and scaling up. Edward Lorenz, a meteorologist and mathematician, described in his 1995 book, "The Essence of Chaos," that chaos theory was a way "to refer collectively to processes … that appear to proceed according to chance even though their behavior is in fact determined by precise laws." More specifically, chaotic systems are subject to sensitivity dependence – more commonly known as the "butterfly effect." Sensitivity dependence means that even slight changes in initial conditions can have a profound effect on outcomes. Mass casualty incidents occur in a complex and chaotic system. So, when faced with sensitivity dependence, rather than relying on plans and procedures that need to scale up to deal with a mass casualty incident, it may be more effective to respond big and scale back if needed.

Thinking and considering complex events is a necessity; repeatedly, reality has proven stranger than fiction. For example, it is unlikely that emergency planners would have constructed a tabletop exercise with a scenario that includes a 9.0 magnitude earthquake that generates a tsunami, causing a meltdown and containment failure at a nuclear power plant. Equally unlikely would be an exercise about a post-tropical cyclone with hurricane-strength storm surge, wherein a few days later there was a snowstorm – all while preparations were underway for a highly contested presidential election. Although both of these high-consequence, low-probability events actually did occur, they fell outside normal planning scenarios.

Considering cascading events can be daunting for emergency planners. There are unfortunately many examples of large-scale non-cascading events that will generate mass casualties. Complex coordinated terrorist attacks, the use of anthrax in the postal system, active shooter events, and a host of other incidents emphasize the need to plan beyond comfort zones. This kind of thinking encouraged several jurisdictions around the United States to acquire medical ambulance buses. By considering large-scale terrorist threats and planning accordingly, these communities were able to make strategic acquisitions and ensure that correct protocols were in place to use these assets in a crisis.

On 15 May 2017, one of these buses was used in support of a mass casualty incident with over 20 injured, resulting from a motor vehicle accident on Interstate-95 in Maryland. Planning for larger events enabled the local jurisdictions to scale down and effectively respond to an overturned charter bus. Had their thinking been reversed – only planning for an incident with two or three or even five casualties – there is no guarantee the capacity would be available to deal with this larger event. Even if the capacity existed, the lack of multijurisdictional integrated planning that results from considering large-scale mass casualty incidents would have hampered response operations.

Challenging the Thought Process

Reasonable people argue that planning for larger mass casualty incidents is time-consuming, that the events are so infrequent that the focus should be on more likely events, and – even if these factors are ignored – that there will never be enough resources in their jurisdictions to deal with such an event. Planning for incidents that stress and break existing response systems is certainly time-consuming. And, yes, a community may never have all the resources it needs to single-handedly manage a large mass casualty incident. However, that is the purpose of mutual aid.

In light of recent mass casualty incidents that have occurred in diverse communities across the nation, frequency is no longer a valid argument. A mass casualty event will happen again. It may happen today. The key lesson to be learned from recent incidents is that the first time determining how to manage such an event should not be as the event is unfolding.

Donald "Doc" Lumpkins, Esq. is the Chief Financial Officer for the Maryland Emergency Management Agency. In this role, he is responsible for the financial oversight of federal and state funding that enhances the preparedness and readiness of the State of Maryland. Before this position, he served in a number of leadership positions within the Federal Emergency Management Agency where he led the development of Comprehensive Preparedness Guide 101, the National Preparedness Goal, and other national doctrine. He holds a Bachelor of Arts from the Georgia Institute of Technology, as well as both a Master of Public Administration and a Juris Doctorate from the University of Baltimore.

Preparing for High-Impact, Low-Probability (HILP) Events

by Jerome H. Kahan

The interconnected global environment can increase the number of vulnerabilities as well as the destabilizing effects of both natural and human-caused disasters. As such, when a high-impact, low-probability event occurs, the consequences can be devastating. To prepare for such events, planners must observe trends, predict futures, and create scenarios for better mitigating any potential threat.

Business and government leaders are facing an increasing number of what are called high-impact, low-probability (HILP) events – or occurrences that cannot easily be anticipated, arise randomly and unexpectedly, and have immediate effects in a world driven by globalized production – as explained in *Business Zone* on 15 February 2012. This observation was stimulated by a January 2012 report by Chatham House, "Preparing for High-Impact, Low-Probability Events: Lessons From Eyjafjallajökull," which notes that the current fragility of the global economy leaves it particularly vulnerable to unforeseen shocks, concluding that "governments and businesses remain insufficiently prepared to confront HILP crises and effectively manage their economic, social, political, and humanitarian consequences."

Interestingly, in June 2011, a comprehensive study on "Future Global Shocks" published by the Organization of Economic Cooperation and Development (OECD) reviewed risk management policies in the face of future global shocks – presumably including HILP events. The report addresses the question, "What do governments and multinational businesses need to do to prepare for the ripple effects of such events and to limit their negative consequences?" Foreshadowing the Chatham House effort, this 139-page study highlights the vulnerabilities of the interconnected, global economy. This study also acknowledges that, "extremely disruptive events, such as earthquakes, volcanoes, financial crises, and political revolutions … have been relatively rare in the past … [but] seem poised to occur with greater frequency in the future," with a destabilizing effect on critical supply systems and adverse economic consequences that extend well beyond the impact point.

Black Swan Events

In an insightful book, "The Black Swan: The Impact of the Highly Improbable," Nassim Taleb explains that "black swan" events mean "outliers" – occurrence that fall outside the range of normal expectations – telling the reader that this term is "derived from the previously held assumption that 'all swans were white' until the discovery of black swans in Australia." However, not all black swan occurrences are HILP, though Taleb claims that, "even though the probability is low, when one … [such] event does come along the … [negative] impact is significant" (e.g., rapid stock market crash), though for some events there can be positive impact (e.g., breakthrough in cancer cures). Whether good or bad, Talib reminds the reader that these unanticipated and consequential events "can have enormous impact on us all."

In his piece, "Black Swans and Strategic Planning," Alan Gleeson, a fan of Taleb's, wrote that "planning becomes more important in times of uncertainty, rather than less so." Hence, observes Gleeson, "once black swan events emerge, businesses need to be very clear as to the likely impact on their particular business and they need to have a robust plan as to how best to mitigate against any negative implications." Thus, in Gleeson's view, strategic planning can no longer be based on merely extrapolating into the future with a few variations, but needs to "include contingency plans related to more extreme events." Then argues Gleeson, planning would then become "a way to measure the difference between what was expected, and what ultimately happens and managing any resultant variances."

Scenario-Based Planning

A fascinating article, titled "Living in the Futures" and published in the May 2013 issue of *The Harvard Business Review*, discusses the concept of "scenario-based planning." Developed by the Shell Oil Company in the early 1970s, its style of scenario planning entails development of a small number of plausible alternative futures that represent different storylines intended to "open the mind to new dynamics [and] create a safe space in which to acknowledge uncertainty." These futures do not extrapolate from the present, but offer planners new ways of thinking about potential worst-case and best-case environments that can lead to hedging strategies.

In an article "Scenario Planning: A Tool for Strategic Thinking" published in the *Sloan Management Review* of January 1995, the well-known economist Paul J. H. Shoemaker argued that, in using this tool to identify trends and uncertainties, "managers can construct a series of scenarios that can expand their imaginations to see a wider range of possible futures. … [This includes plausible examples of HILP events] that will enable them to be much better positioned to take advantage of the unexpected opportunities that will come along." In short, Shoemaker claims that "scenario planning attempts to capture the richness and range of possibilities, stimulating decision makers to consider changes they would otherwise ignore, … [while organizing] those possibilities into narratives that are easier to grasp and use than great volumes of data … [and above all] challenging the prevailing mind-set."

In traditional models of strategic planning, the method often used is to establish a "base case" and then conduct "best case" and "worst case" scenarios. But as three planners from McKinsey & Company pointed out in April 2009, this approach is no longer valid approach given the profoundly tumultuous future environment. However, scenario-based planning can come to the rescue by developing plans on the assumptions that several different futures could occur and that attention should be focused on the underlying drivers that can shape theses futures.

Other Challenges

Published in 2012, "Strategies for Managing Low-Probability, High-Impact Events" investigates lessons that can be learned from recent "megadisasters" – unexpected manmade or natural catastrophes of exceptional severity that cause unusually harsh damage with HILP features. In essence, this study concludes that every country should develop strategies for managing events that reflect their own as well as global experiences with megadisasters. These integrated Disaster Risk Management (DRM) strategies, the study concludes, should integrate structural and nonstructural measures tailored to local conditions, as well as forecasting and early warnings, land-use planning and regulation, hazard maps, education, and evacuation drills.

These proactive approaches to disaster preparedness are needed in order to avoid reactive thinking when a disaster occurs.

On 28-29 September 2015, a workshop entitled "Preparing for High Consequence, Low Probability Events: Heat, Water & Energy in the Southwest" was held at the University of Arizona to investigate how to deal with the increase of severe heat waves and extended droughts in the southwestern United States. Such events have increased the risk of "constrained water resources in the region, … [with participants including] regional researchers and resource managers with expertise in water, energy, climate, natural hazards, and emergency management." Workshop participants investigated many recent case studies, focusing on "important impact cascades spawned by the plausible combination of drought and heat waves leading to diminished water supply and power outages – a low-probability combination of events – but one of high consequence if it occurred." When these events occur and are subjected to analysis, participants note that they "provide windows of opportunity for managers and planners to learn and use gained knowledge to plan for future events – in other words, 'never let a crisis go to waste'."

Recommendations

The Chatham House report recommends that to find the right balance in planning for specific known events against "creating generic responses for events that are rare or unexpected, governments must strengthen planning processes to anticipate and manage shock events … [by identifying] common activities and actions that are relevant in the majority of disruptions." In this connection, participants at the University of Arizona Workshop as well as McKinsey experts agreed that the use of scenario-based planning would ensure that a long-term perspective is taken to enable decision-makers to be proactive rather than reactive in their thinking. Involving key decision-makers in "red-teaming" future scenarios by providing opposing views can help prepare for unexpected future events, notably "black swan" events with HILP features. Finally, it is always useful to gather scenario planners into a room to conduct "hot washes" – after-action evaluations following the production of a set of future scenarios – to help ensure that these will result in sufficient preparations to deal with future extreme and unexpected crises, whether or not such a crises actually materialize.

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When Pandemic Management Meets Cybersecurity

By Nitin Natarajan

When faced with a health crisis such as a pandemic, the primary objective is ensuring the health and well being of the public and finding the fastest and easiest method to limit the spread of disease and take care of those who are sick. Cyberthreats can hinder public health efforts if mitigation steps are not taken and partners are not engaged before a pandemic or other public health crisis occurs.

An immense amount of resources is dedicated to a wide variety of challenges including epidemiological investigations, medical countermeasure dispensing, public communication and education, workforce training, and a myriad of other issues. However, one common aspect of all of these items that is overlooked is cybersecurity. Often, the cyberrisks involved in a massive healthcare or public health crisis are not considered. In these circumstances, the most vital data is often at risk – especially because people are not looking at a pandemic with the eyes of a cyberattacker.

Cyberthreats & Steps to Mitigate Them

Consider the types of information that are being used in times of crisis, how this information is being accessed and by whom. The need to surge staffing during emergencies can lead to the potential for unsecured systems or unsecured access points. Staff who may not have frequent experience with particular information technology (IT) systems may now require access. This combination can lead to potential vulnerabilities with personally identifiable information, electronic health records, or sensitive operational response systems. New users on a system during a period of heightened activity also leave users more susceptible to common types of vulnerabilities such as phishing attacks, due to the users' lack of familiarity with the system, sensitive data handling procedures, and security protocols.

When looking at securing sensitive data within the healthcare and public health sectors, the focus is often on personally identifiable information and clinical patient data. These systems typically have strong pre-established security processes. Even in the midst of a disaster, care must be taken to ensure that security processes are followed and maintained. Large amounts of personal data are often readily accessible at multiple emergency locations, and the public is often carrying personal data to hand over to emergency workers in a less than private setting. These factors should be proactively addressed before setting up local operations and again while operations are ongoing.

In addition, emergency operations, logistical, and supply chain data may be readily accessed. Sensitive information – such as where vaccines are being produced, how, where, and when they are being shipped, and quantities of products that are at specific locations – may be subject to theft. The dangers in this situation come from many angles. In addition to potential global threats (including potential nation state actors), many attempts for access may be from local individuals looking to collect data in an attempt to better protect themselves or

their families. Perceived shortages of pharmaceuticals or vaccines may cause bad actors to illicitly collect information on the whereabouts of existing supplies to ensure that they can obtain their allotment, through peaceful or less than peaceful means.

Within the healthcare space, bad actors – both internal and external to the organization – looking to exploit the crisis may use the surge in hospital patients and traffic to infect medical devices and hospital networks. As recently as 2017 with the "WannaCry" ransomware attack, hospitals have suffered significant impacts from cyberattacks.

Although concerns about bioterrorism always exist, there have been repeated instances of naturally occurring biological outbreaks, including the Zika and influenza viruses. Despite the ever-present threat, there are steps that can be taken to help mitigate the impacts of a cyber incident during a public health emergency. Local, tribal, state, territorial, and federal government agencies can take several basic steps to better prepare for the vulnerabilities that exist at this nexus between physical and cyber preparedness:

- Engage all partners;
- Evaluate and update plans; and
- Exercise plans.

Engaging Partners

Engage in an "opt-out" model versus the traditional "opt-in" model. Often when preparing for emergencies, planners invite organizations they believe have equities in what they are facing. However, this common approach has one significant flaw, it assumes that the individual bringing the groups together understands all aspects and nuances of the potential partners; something no one has the ability to know. For instance, during the recent Ebola outbreak, some jurisdictions did not engage their environmental departments to assist in waste management. The assumption was that, if healthcare facilities, public health, and transportation agencies were involved, all equities were covered. However, medical waste management is regulated at the state level, and engagement of state environmental departments was critical. An opportunity to "opt-out" would allow all pertinent agencies to engage earlier in the incident. This can potentially avoid challenges such as those related to hazardous materials handling and final waste dispositions that were encountered in the response. The next time an incident requires a complex multi-agency response, extend the initial invitations to all potential partners.

Existing emergency plans should already identify agencies, departments, companies, offices, or business units that lead or support various types of responses, so do not spend time trying to decide who should or should not be involved in the initial conversations. Invite all identified partners and, if they do not identify any equities, let them "opt-out" of future efforts.

Plan, Evaluate & Update. Conduct thorough and meaningful reviews of existing emergency plans. Often, reviews are conducted to assess the adequacy of the existing plan against the current conditions, but, in order for plans to have an effective shelf life, it is important to review plans against current and potential future conditions. Organizations have a variety of tools to identify potential future threats, including existing hazard vulnerability analyses or the FEMA Threat and Hazard Identification and Risk Assessment program. Although there are many different models out there, the accuracy and confidence in the data entered into the model to drive the outcome are more important than which model is used. Once the reviews are conducted, ensure updates are practical and able to be operationalized. All staff members – including those who may be called to assist during a crisis – need to be trained on the updated plans.

Exercises. The plan is not final until the exercise is complete. Prior to that, the plan is still a concept. Exercises are often perceived as requiring extensive planning and expense; however, with a progressive exercise program, response components can be evaluated with minimal staff and operational impacts. Plans should be exercised with all key partners and need to be conducted in a method that allows areas for improvement to be addressed before subsequent, more complex exercises.

Continued Progress

Significant progress has been made over the past two decades in preparation for public health emergencies and bioterrorist attacks but these preparedness efforts have often not factored into coordinated cyberattacks. However, cybersecurity challenges have grown at a pace far exceeding the challenges in the public health community. As cybersecurity vulnerabilities and attacks throughout the healthcare and public health sector continue to occur, careful and effective planning and preparedness can help mitigate the effects of these attacks, especially during large-scale public health crises. Engaging in ongoing and localized training and exercise programs and continuously updating emergency preparedness plans also help to mitigate the risks of cyber attacks during public health emergencies.

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Planning for the Community vs. Planning for the Plan

By W. Craig Fugate

Imagine a family losing their home, their belongings – everything. With nowhere to go, they find the nearest shelter, only to be turned away due to shelter restrictions. Maybe it was because they have a dog, or one of their children has a disability, or they have an elderly parent with them. Regardless of the reason, they are turned away. When planning for a community, that should never happen.

When I was a state emergency manager, we created shelter annexes for each of these types of individuals – they were not included in the core plan. After Hurricane Andrew, a Category 5 storm that struck south Florida in August 1992, there were a lot of people coming to shelters who were on oxygen. Creating a separate special-needs shelter for them meant that, when these people showed up to their nearest shelter, they were told to go elsewhere. They could not go to the closest shelter, which did not accommodate people who relied on public transportation or had lost their cars in the hurricane. It also meant that these people could not be with their families – an absurd thing to ask during a time of crisis.

That was a mistake. This should never happen.

Root Causes

Unfortunately, too many emergency managers do not take into account the community as it exists. Instead, they create a plan based on an idealized community, and people are invariably left out. Communities are complex. In every neighborhood, there are elderly folks, people with disabilities and challenges, people with pets, and people with children.

Everyone in the community should be involved from the start. That includes planning for how to communicate with everyone – how to disseminate critical information – throughout the emergency. Some people are hard of hearing or visually impaired, and details must be included on how to reach these people so they know where to go and what to do.

Some emergency managers do not have the time or money to ensure shelters are set up to accommodate the entire community. Others simply do not know where to turn or who to ask to accommodate all members of the community. Both of these situations point directly to a key solution: include the community in the plan, and include the community in the response. Resources and knowledge are already part of the community and should be included at the table from the start and throughout the response.

There are so many advantages to this approach – most importantly, a more effective response. If that is not enough of a reason, consider the money and resource savings. For example, a local grocery or big box store included in a plan is able to provide resources more quickly – and likely at a much cheaper cost – than having those resources provided by the government.

A Community's Response Done Right

The response to the 2011 EF5-rated tornado that struck Joplin, Missouri, was a textbook example of what to do right:

- They used a local college as shelter and invited everyone in.
- There were nurses at the shelter.
- They had set up a place where pets could be cared for.
- They brought in people who could watch over children.

It was a huge shelter. Those who arrived were not turned away, no matter what. Everyone was included. To get it all set up, they turned to the community they lived in to help create a plan for that very same community. Everyone worked together: the local county, city, school board, and college; the local Red Cross chapter; the local Humane Society; and local nurses and veterinarians. Each of these parts of the community worked together as a single team to help create an "inclusion shelter." And, it worked.

Administrator Craig Fugate surveys a damaged fire station with a Joplin firefighter. FEMA is continuing to support disaster survivors and the community affected by the deadly tornado of May 22. *Source:* FEMA/Bradley Carroll (25 May 2011).

One more thing: Do not be afraid to incorporate the private sector. The private sector is a huge part of the community. In Florida, one of the best resources was a local veterinarian who helped design protocols for how to incorporate pets into these inclusive shelters. In addition, local grocery or big box stores are already accustomed to providing resources to large groups of people.

It is easy to create a plan for some idealistic community that does not exist. That plan will fail. It is the responsibility of emergency managers to plan for the communities they live in, not for a community that fits nicely within their plans.

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Responding to Unique Operating Environments

By Seth Komansky

First responders are often deployed to unique operating environments, which include large-scale special events with many participants and spectators: street festivals; road races or marathons; concerts; and sporting events. These environments require leadership to take a forward-thinking posture in the planning process to develop strategy. It also relies on front-line personnel to execute tactics that vary from day-to-day operations.

Emergency Medical Services (EMS) is called to respond to an increasing number of incidents that occur within unique operating environments (UOEs). These environments have the potential to tax available resources or challenge standard methods for response operations.

Challenges

Considering the landscape at UOEs, for most jurisdictions, the population surge to a condensed area creates the greatest challenge. With any mass gathering, EMS responds to all of the usual call types, both medical and traumatic in nature, including: allergic reactions; cardiac and chest pain; respiratory; trips and falls; heat-related emergencies; or overdoses. However, these UOEs pose the challenge of seeing these calls at a much higher volume. Normal deployment models do not account for the surge of people into an area usually covered by a single response unit, such as college and professional sporting events or concerts. Although there are defined times for the actual event, spectators tend to arrive many hours earlier to partake in tailgating activities. This expands the footprint of the event beyond the confines and comforts of the walls of the stadium. Stadiums can hold 60,000-100,000 people and that number soars with those who just come for the tailgating to enjoy the environment. Hazards such as hot grills, the combination of moving vehicles with intoxicated pedestrians, and environmental exposures could increase call volume.

Street festivals pose similar challenges to the sporting events and concerts. A significant difference exists: these events typically occur on roadways that are traditionally open to moving traffic. The road closures inherently challenge EMS response, both within the event and to the nearby buildings for routine requests for service. It also increases vehicular traffic to nearby streets, thus complicating response. Further, the surge of population tends to sprawl beyond the confines of the event footprint to area parking decks or parking lots, area businesses, and nearby roadways and sidewalks.

When considering a road race or marathon, EMS must take into account the sprawling nature of the event. Although the route is defined, a single event crew cannot possibly cover the entire route effectively. This is particularly true of a marathon or triathlon, which may sprawl over several jurisdictions. This requires coordinated planning with several different stakeholders. Road closures and changing detours complicate response by potentially closing

typically used routes to calls outside of the event. It is important to communicate with race coordinators to determine if participants' medical history and contact information will be on the back of their race bibs in the event the runner is incapacitated. If not, knowing who will have the participant emergency contact information is critical.

With any of these situations, a mass casualty or multi-patient incident is increased just by the inherent fact that there are more people in a smaller and compact area. In addition to all of the above challenges, those responsible for planning must consider a nefarious act at any of these venues or footprints. Threats using small arms, edged weapons, improvised explosive devices, or vehicle ramming remain just a few things to think about when evaluating the "what ifs" for low-frequency, high-consequence incidents.

A Unique Approach for a Unique Operating Environment

In order to best approach the management of a UOE, a unique outlook and approach are needed. First and foremost, each EMS system must develop a way to communicate with community leaders and planners from a variety of disciplines, particularly with those responsible for organizing events. If not part of the permitting approval process, it is important to communicate with those that are to ensure cooperation with approved events and perhaps have input on potential impacts prior to the event's approval. Without the awareness of an event happening and not having a seat at the planning table, EMS considerations may be lacking.

Population surge and event sprawl are just two factors that create unique operating environments for first responders. Planning is key.

Internally, it is important to establish resources on hand to manage the challenges the event presents. These could include ambulances and personnel, but also specialized services and units trained to deploy to UOEs such as bike teams, foot teams, carts, command assets, and command posts. Each of these assets has its own advantage. For example, a bike team is able to reach much further in a quicker time frame than a team on foot and typically with greater ease and more safely than an ambulance crew. In more crowd-dense areas, bikes may not be able to navigate the crowds, leaving a foot team as the best option. In both cases, they are limited with transport capabilities to a rendezvous point with an ambulance, so the use of carts or a utility vehicle modified with a stretcher mount or space for a supine transport on a backboard or other similar device and/or seating would be a better option. A combination of these resources improves capabilities. It is beneficial to work smarter, not harder!

It is also important to consider allied partners, "Do the hospitals in your area have response teams or assets that may be used for triage or treatment, cooling stations, or workforce multipliers in these environments?" If so, with daily interaction with these hospitals, this partnership would likely be seamless.

EMS systems must have a way to "flip the switch" for a modified operations plan when working with these UOEs. When there is an event that is either resource dependent or results in a mass casualty or multi-patient incident, the ability to mobilize an appropriate response becomes necessary. Some ideas to incorporate into this plan include:

- *Staging areas:* Evaluating possible staging areas able to accommodate all responding disciplines and apparatus. This could be a regionalized concept so the jurisdiction has some predetermined areas and these may also be used during normal operations. Remember, a desired parking lot differs in usability on weekdays to weeknights and weekend days to weekend nights. It is important to assess these options for various operational periods.
- *The incident within the event:* There needs to be some foresight to determine how incoming units will integrate into an already existing organizational structure. Regardless, whether treating it as an incident within the event, to build a new incident command structure, or using the existing structure to build divisions or groups into the existing command structure, the threshold for a mass casualty or multi-patient incident should be considered to determine when to execute the plan.
- *System coordination:* Whether operating a single department or multiple departments in a single jurisdiction or across several jurisdictions, it is important to establish a person who can step back and take on the roll of "air traffic controller." Ideally, if possible, this could be someone who takes a position at the dispatch center helping to make decisions about changes to deployment. It is a strategic position and should be a person with the knowledge and authority to alter responses. This modification allows for the following: vetting and altering traditionally multi-unit responses to fewer or even single units during this time period; determining which calls can be held for a period of time; or calling and managing other mutual aid. By removing this person from the mix of the other operations, they are able to objectively assist with managing all of the other needs and requests for service, modifying response as appropriate. Ideally, as guidelines, modified operations plans are developed ahead of time, such as for severe weather, time when resources are depleted, or when an incident occurs at a UOE.
- *Transportation decisions:* Having transportation plans ahead of time allows for less just-in-time decision making for crews on the scene in the heat of the moment. This determination requires early communication with the emergency departments about a multi-patient response. If possible, it is beneficial to disburse patients to several facilities instead of overloading a single location. Working on relationships early with area mass transit bus options or local school district bus assets are good options to move many people with few ambulances.

Building the Ranks

The initial groundwork at an incident within a UOE must be laid early on, sometimes before senior leadership and command staff arrives on location to build out the incident command system. With this in mind, it is just as important to build the capabilities of front-line personnel as it is to continue to develop the leadership's incident command capabilities. Building the team through tabletop or scenario-based training not only improves comfort of incident management at UOEs, mass casualties, and multi-patient incidents, but also utilizes sharing of ideas and collaboration to support best practices. This further allows for the reinforcement, familiarization, and review of standard operating guidelines, protocols, and agency policies.

Additionally, specialized training should be delivered to those who serve on special operations or specialized service units operating in these UOEs. The need to incorporate unit-specific training for bike teams, venue-specific teams, or special event units should incorporate the protocols used in routine operations coupled with the challenges faced in these environments. The goal is for personnel to sharpen their skills for unique delivery.

Preparing for Future Events

The reality is communities will continue to host events and street festivals, performers will continue to put on concerts for fans, and sports teams will continue to compete. EMS should support these UOEs within the communities served and, as a discipline bridging the public safety and healthcare industries, EMS has a responsibility to deliver services in these environments. Of course, while it is easier to have a grasp on an event before a major incident occurs within that event, through enhanced awareness and planning – and by modifying a few plans and delivering training for UOEs – personnel become increasingly comfortable and prepared to operate within these environments, either as deployed and dedicated assets or when responding to a 911 call and arriving first without a pre-deployed cache of assets and personnel.

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Wearable Sensors for Chemical & Biological Detection

By Richard M. Ozanich

One of the strengths of the Pacific Northwest National Laboratory (PNNL) is the ability to conduct comprehensive technology foraging and objective assessments of various technology areas. This article highlights leading research by others in the area of chemical and biological (chem/bio) detection that could be further developed into robust, highly integrated wearables to aid preparedness, response, and recovery.

The current wearables market is approximately $5 billion and projected to grow to over $15 billion in a couple years, and to $50 billion by 2023. Fitness and sports wearables that monitor various physiological and biomechanical parameters comprise the bulk of units currently sold. Health care wearables offer improved monitoring of at-risk patients with inherent overall medical cost savings and are rapidly growing in capability and utility. Wearables can also monitor farm animals, high-value animals (e.g., zoo animals, racehorses), and even pets.

Although most consumer products measure only a subset of the following parameters, more specialized wearables, including those used in health care (which tend to be much larger), may include:

- Heart rate
- Skin temperature (core body temperature is still under development)
- Breathing rate
- Ultraviolet (UV) light exposure
- Blood pressure
- Electrocardiogram (ECG) – heart
- Electroencephalogram (EEG) – brain
- Electromyography (EMG) – muscle
- Acoustic (coughing, wheezing, heart sounds)
- Blood oxygenation

Additionally, using advanced algorithms, "composite" sensor measurements can provide estimates of activity/mobility/falls (using three-axis accelerometers), distance traveled, calories burned, sleep quality, stress/exertion/fatigue, among many others.

Although the most common wearable format is a smartwatch, other forms are being developed including glasses, chest straps, skin "tattoo" sensors, jewelry, earrings, clothing/textiles, and even implantables (e.g., for glucose monitoring). The wearables discussed above are mostly "inward looking" sensors (i.e., self-monitoring). Not traditionally considered a

"wearable," dosimeters or utility-belt-worn devices ("outward looking" or environmental sensors) can offer valuable information for improved safety and health, particularly for emergency responders. For example, people with asthma or other respiratory ailments can currently wear small, real-time respirable particulate monitors. Miniaturized analytical instruments and dosimeters are also available for measuring various chemical species and biological agents.

Essential Developments to Enable Chem/Bio Wearables

The above parameters and composite measurements for inward-looking wearables are based on physiological and biomechanical measurements and often suffer inaccuracies. Eight enabling technology areas summarized below are essential to developing future advanced wearables.

- *Miniaturization* – Miniaturized instruments (e.g., Raman, Fourier transform infrared spectroscopy [FTIR], mass spectrometry), dosimeters, airborne particulate/biological monitors, and microfabrication/microfluidic platforms allow multiple complex measurements and operations to be conducted in very small form factors, including polymerase chain reaction.
- *Biomarkers of disease/exposure* – Many prodromal indicators of exposure to harmful chemical or biological agents are known, but these are often associated with several possible causative agents or conditions. Biomarker suites are likely to improve the identification of specific causative agents, and this is yet another challenging but necessary area requiring ongoing research.
- *Nanomaterials* – Nanomaterials allow faster, more rapid and sensitive detection in very small sizes.
- *Sensors* – Implantable sensors are the ultimate in ease-of-use, but they have limited ability to measure chem/bio species and have challenges associated with long-term accuracy. Stable and reversible chem/bio transducers are a particularly challenging area requiring further development.
- *Robust/flexible electrical systems* – Numerous researchers have demonstrated various approaches to designing and producing stretchable tattoo sensors, including important advances by Joseph Wang (University of California, San Diego), John Rogers (University of Illinois, Urbana-Champaign), and others. Wang recently developed wearable glasses that incorporate sensors in the nose pads to measure sweat electrolytes and metabolites. Rogers' "Biostamp" includes an impressive array of transistors, diodes, capacitors, inductors, oscillators, temperature sensors, strain gauges, light emitting diodes, together with an inductive coil and antenna that can serve as a platform for various sensors.
- *Transdermal biological fluid extraction* – Current research is rapidly advancing the suite of chem/bio parameters measurable in sweat, interstitial fluid, and blood using sweat inducer/collectors and microneedle arrays. Jason Heikenfeld

and others at the University of Cincinnati Novel Devices Lab recently reviewed the field of wearable sweat sensors.

- *Microscale power/storage* – This continues to be a challenge for long-term wearables operation, but incremental progress continues, including the use of energy harvesters from movement, light, and heat.
- *Communications* – Data transmission, storage, management, analytics, security, and use of the cloud present an area where continued essential developments will enable effective chem/bio wearables.

Notable Chem/Bio Wearables

Hyunjae Lee et al. at the Korea Center for Nanoparticle Research demonstrated a highly integrated wearable system on diabetic mice that includes a graphene-based electrochemical device for glucose monitoring and a thermally activated polymeric microneedle array for sampling interstitial fluid and administering drugs. Dongyang Cai et al. at the State Key Laboratory in Beijing, China, developed an integrated microfluidic device that uses dielectrophoresis to extract up to 20 different pathogens from blood followed by 4-channel polymerase chain reaction for identification in nanoliter volumes. Wei Gao et al. at the Department of Electrical Engineering and Computer Science at the University of California Berkeley demonstrated an unprecedented degree of integration in a multiplexed sweat sensor that incorporates complex signal conditioning on a flexible printed circuit board combined with a skin-interfaced flexible sensor array for monitoring hydration status in real-time. The sensors measure metabolites (glucose and lactate) and electrolytes (sodium and potassium ions) and use a skin temperature sensor to improve sensor accuracy. Results are wirelessly transmitted to a smartphone. The wrist-worn system was shown to enable the monitoring of hydration status on humans engaged in prolonged indoor and outdoor physical activities.

Future Outlook

Wearable devices show great promise for improving the health, safety, and effectiveness of emergency responders, but they require ongoing research in numerous areas. Key enabling technology areas include: (a) biomarker panels of disease or exposure; (b) stable/reversible chem/bio target receptors; and (c) nanomaterials for faster, smaller, and

more sensitive detection. As with the evolution of the cellphone, wearables are expected to improve in capability, usability, and affordability as enabling technology allows higher degrees of integration in ever-smaller form factors.

About Pacific Northwest National Laboratory (PNNL): Interdisciplinary teams at PNNL address many of the United States' most pressing issues in energy, the environment, and national security through advances in basic and applied science. Founded in 1965, PNNL has a team of 4,400 staff and an annual budget of nearly $1 billion. It is managed by Battelle for the U.S. Department of Energy's Office of Science. As the single largest supporter of basic physical science research in the United States, the Office of Science is working to address some of the most pressing challenges of the time.

Richard M. Ozanich, Ph.D., is a senior research scientist at Pacific Northwest National Laboratory (PNNL) and has worked in the field of biodetection for over 25 years. He is a subject matter expert in biodetection and optical spectroscopy and has a broad base of knowledge in the fields of chemistry, biology, measurement instrumentation, and wearables. He is actively involved with technology foraging of current and future biodetection and wearables approaches and he leads a standard development effort for biodetection instrument and assay evaluation. He is working on the development and implementation of a universal operational field assessment process for emerging innovative technologies that show promise for emergency responders and is developing rapid enrichment media for pathogenic bacteria. He has demonstrated systems for Bacillus anthracis detection incorporating a smartphone microscope for real-time imaging and video and led a team of scientists that evaluated the performance of 35 different field-portable biothreat detection products. His prior experience includes development of automated fluidics, micro- and nano-particle assays and flow cytometric methods to improve speed and sensitivity of pathogen detection.

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