

Emergency response is an inherently dangerous occupation. Emergency responders face a wide range of serious hazards in their jobs, which places them at high risk for occupational injury or death. This risk is mitigated by their using various forms of personal protective technologies (PPTs), such as protective garments, respiratory protection, environmental monitoring and communications equipment, and practices and protocols that focus on safety.

This report addresses the safety of emergency responders by examining the hazards and personal protection needs that members of the emergency responder community regard as being the most important. The findings reported here are based on in-depth discussions with 190 members of the emergency response community nationwide, including structural firefighters, emergency medical service (EMS) responders, police officers, emergency management officials, technology and services suppliers, researchers, and program managers from 83 organizations around the country.

The principal topics addressed in this report include:

- The primary tasks that emergency responders undertake
- Situations in which the risk of injury is the greatest and that have the highest priority for improving personal protection
- Current and emerging technologies that are critical to protecting the health and safety of emergency responders
- Drivers of, impediments to, and gaps in technology development.

PROTECTING FIREFIGHTERS

Firefighters who participated in this study consistently noted that their protective clothing (turnouts or bunker gear)¹ provides excellent flame retardance and thermal protection. However, despite the high protective capability of current firefighter clothing materials and components, several protection challenges remain.

A firefighting ensemble composed of highly effective components can nevertheless leave firefighters vulnerable to injury due to component incompatibility or bodily exposure at component interfaces, with mismatched gloves and coat cuffs often cited as examples. To address such problems, study participants recommended increased “configuration control”—the standardized specification of component dimensions and interfaces.

Reducing thermal and physical stress is a top priority among the firefighters with whom we met. The thermal protective ensemble, including turnouts, boots, gloves, and hoods, almost completely encapsulates a firefighter, which creates difficulties in dissipating body heat. The weight of the protective garments, self-contained breathing apparatus (SCBA), and firefighting equipment puts firefighters at high risk of injury from physical stress and overexertion. Study participants pointed to several approaches to addressing this problem, including increasing the vapor transmission of turnout textiles and improving the fit of turnout gear to increase its flexibility and comfort. Another suggested approach is the implementation of physiological monitoring and communications systems to provide advance warning before firefighters suffer heat stress or exhaustion.

Firefighters noted that they are generally very satisfied with the respiratory protection afforded by modern SCBA. However, study participants also observed that there are situations in which alternative forms of respiratory protection may be appropriate, such as during fire overhauls² or during search-and-rescue operations after a structural collapse. Some participants cautioned, however, that any such alternatives would provide less respiratory protection, a consideration that must be weighed carefully in any decision. Discussion participants also called for ways to improve SCBAs, citing the desire for lighter and higher-capacity air bottles and improved air supply monitoring and warning capabilities.

¹Firefighter protective clothing, commonly referred to as *turnouts* or *bunker gear*, consists of flame- and water-retardant pants and overcoat.

²*Fire overhaul* begins when the main fire has been suppressed. It entails activities such as searching for hidden hot spots, salvaging property, and cleaning up debris and equipment.

Improving communications for individual firefighters is another high-priority area mentioned by study participants. They repeatedly pointed out that firefighters have great difficulty communicating person-to-person and over a radio while wearing an SCBA face mask. Some participants further observed that their radios are not designed specifically for the needs of a firefighter, which is a result of the relatively small market share that emergency responders represent.

Improving *fireground accountability*, the ability to account for the whereabouts of firefighters at an incident scene, was also viewed by larger fire departments as a high priority. Many firefighters are injured or do not receive prompt treatment for injuries, participants claimed, because of confusion over the location and activities of individuals during an incident. Existing accountability systems that rely on manually transferring personal identification tags to status boards were viewed as being outdated. Innovations utilizing magnetic card readers, which were discussed by several participants, may provide improved accounting system flexibility and reliability.

PROTECTING EMERGENCY MEDICAL SERVICE RESPONDERS

Discussion participants representing the emergency medical services commonly claimed that little protective equipment designed specifically for their work environment is available. And what does exist is often low quality, uncertified, or impractical. To remedy this problem, some organizations were adopting PPT, such as SCBAs, bunker gear, and armored vests, from the fire and law enforcement services. One reason cited for the shortfalls in EMS protection is that no federal agency is dedicated to addressing personal protection issues, such as equipment, standards development, certification, and PPT usage enforcement for the emergency medical responder community, and little funding is dedicated to address these issues. Addressing protection needs is further complicated by the wide range of tasks that EMS responders undertake and the multiple types of agencies that provide emergency medical response service.

Emergency medical service responders expressed a strong concern about exposure to infectious diseases such as AIDS, hepatitis C, and tuberculosis. Although exposure to infectious diseases accounts for very few actual responder injuries or illnesses, pathogens were seen as a growing hazard and one of the most difficult hazards to protect against. Emergency medical responders typically have access to protective gloves, masks, goggles, and splash gowns. However, this gear is often designed for hospital use and is sometimes difficult to use in the field. Study participants in several EMS departments noted that usage of this gear has increased considerably through the issuance of fanny packs containing an ensemble of protective gear, which make the gear more easily accessible.

Another hazard of increasing concern to EMS personnel is physical assault. Unpredictable circumstances leave EMS responders particularly vulnerable to surprise attacks and other violent acts. In response, many EMS personnel are now being trained in situation management and self-defense. EMS responders in many larger departments are also being issued body armor. However, the use of body armor is left to the discretion of individuals, and its use is estimated to be rare.

Like emergency responders in all services, EMS responders are concerned about hazards associated with terrorism. The top concern in this area is exposure to biological and chemical warfare agents, either direct exposure or exposure while treating victims. EMS participants expressed a desire for improved hazard assessment training, as well as better respiratory protection and protective clothing options, to deal with these hazards.

PROTECTING LAW ENFORCEMENT OFFICERS

A conclusion that emerged from our discussions with law enforcement representatives is that protecting law enforcement personnel may be the most challenging personal protection task within the emergency response community. This finding stems from several factors: Law enforcement responders are typically the first responders on the scene of an incident and hence have the least advance information about potential hazards; their mobility and patrol requirements limit the amount of gear they can wear or carry with them; their appearance requirements, particularly for covert operations, limit their protection options; their being on patrol rather than returning to a station between calls limits training opportunities; and most personal protective technologies are not developed with the law enforcement mission and operating environment in mind. In addition, law enforcement lacks a centralized professional organization dedicated to health, safety, and protection. As with EMS, law enforcement often turns to fire service resources for guidance.

The ballistic vest is the most widely used personal protection technology in law enforcement. Despite their proven effectiveness, police often do not wear vests because they can be hot and uncomfortable, particularly while riding in a car. Vest designs have improved over the years to address these concerns, but the design improvements have been achieved, in part, by reducing the size of vests, and some participants expressed concern that body coverage was too small. Alternatives such as “throw-on” armored jackets were mentioned as an option, though participants noted that those jackets might not be readily available when needed.

Automobile injuries are another area of concern. Representatives from a number of departments noted three main problems contributing to automobile

driving hazards: (1) The side placement of computers and radios can cause officers to become distracted while driving and can present impact hazards in accidents. Study participants called for in-dash systems and overhead displays to improve safety. (2) High-speed, rear-end collisions are also a serious problem, and participants suggested strengthening automobile frames, adding rear-impact safety devices, and improving vehicle warning lights. (3) Finally, unsafe driving behavior, particularly in younger officers, is a major contributor to accidents and could be mitigated by stricter driving policies or by speed monitoring or governing systems.

Pathogen protection is another concern among law enforcement responders, particularly protection from pathogens transmitted during physical assaults such as biting or spitting. While many patrol cars are stocked with disposable gloves and sometimes also masks, these items are difficult to access quickly and are rarely used.

PROTECTING RESPONDERS FROM TERRORISM

A concern expressed by the entire emergency responder community is adequate protection against terrorist attacks and the vulnerability of nonspecialist first responders in particular. Accordingly, several emergency responder departments have begun equipping their vehicles with chemical protective gloves, suits, escape hoods,³ and respirators.

RAND's discussions with participants revealed that the issue of providing protection for chemical, biological, or radiological (CBR) terrorism is complicated by several uncertainties:

- Many police and fire department representatives felt that they did not know what they need to be protected against, what form of protection is appropriate, or where to look for such protection. Such uncertainty frustrates efforts to design a protection program and acquire the necessary technology.
- Participants were unsure how well the available protective technologies will work for anticipated situations. While hazardous materials (hazmat) protection is subject to rigorous standards and certification procedures, hazmat equipment and usage protocols are designed primarily around the conventional model of hazmat response to industrial accidents. Much of the available hazmat protection is neither designed nor certified for this new role of terrorism response.

³An *emergency escape hood* is a soft-sided pullover hood with an elastic neck seal. These hoods provide particulate and chemical respiratory protection to enable wearers to exit hazardous environments.

- Participants were unclear how personal protective technology is expected to be used in terrorist events. Because of the uncertainty surrounding the roles of responders in such situations, major questions remain as to exactly where such equipment should be stored, when it should be donned, what tasks should be performed while it is used, and who should make these decisions.

BEYOND THE INDIVIDUAL: SYSTEMS-LEVEL PROTECTION

In addition to protective clothing and other personal gear that supports a single individual, several other forms of emergency responder protection operate at the command or unit level. Such “systems-level” protection mentioned by participants includes communications, location monitoring, hazard monitoring, and various human factors.

Communications

Beyond the tactical communications issues that firefighters face (discussed above), a number of police, EMS, and fire departments emphasized strongly that there are fundamental problems with the radio communication systems currently used by emergency responders. Departments often use incompatible radio systems and cannot communicate easily with each other at the scene of major incidents. This problem affects communications among local departments as well as communications between municipal departments and state or federal agencies. Such communications breakdowns can have severe consequences. For example, incident commanders may have difficulty in maintaining scene control, utilizing forces most effectively, or sharing critical safety information.

This problem is being addressed by a push toward implementing a uniform, interoperable radio system for emergency responders. While this radio system—a digital, 800-megahertz backbone system—has many advantages over analog radio-to-radio technologies, many departments that had acquired these systems were not fully satisfied with their performance. Their concerns include the inability to talk over other users, unreliable signal transmission in areas with tall buildings or hills, and the high investment costs. As a result, departments often resort to maintaining multiple systems to handle all of their communications needs.

Hazard Assessment

An important part of protecting emergency responders is understanding the hazards that they face. While generalized models based on empirical evidence provide much of the basic input on protection choices, incident-specific information can further characterize those hazards and inform protection and procedural decisions. Several hazard-assessment tools were mentioned in the discussions, including:

- On-site information, such as hazmat placards
- Facility “pre-plans”⁴
- Information supplied by dispatchers
- Environmental monitoring equipment.

Participants noted that all of these methods can provide useful information, but that they suffer from various shortcomings that limit their applicability. Interestingly, most participants stated that hazard information is often used to guide operational decisions but rarely influences personal protection selection because protection options are very limited to begin with.

Personnel Location Monitoring

A longer-term but potentially very valuable technology for larger services is personnel location monitoring. Participants from both fire and police departments made mention of this technology and noted that the primary benefit would be the ability to quickly locate a trapped or injured responder. The technology could also assist in managing operations, guiding personnel through buildings, improving dispatching efficiency, and managing driving behaviors. Several participants have begun investigating emerging technologies based on the Global Positioning System (GPS). Such systems, however, are expensive and, more fundamentally, suffer from poor vertical resolution and signal penetration problems. Other location technologies under discussion and in development utilize radio triangulation (exploiting differences in travel times of radio signals between a source and multiple receivers), radar (exploiting the travel time of reflected radio signals), inertial tracking (using accelerometers to compute cumulative movement; also known as “dead-reckoning” systems), and hybrid systems.

⁴*Pre-plans* comprise site-specific information compiled beforehand, such as information on hydrant and standpipe locations, utilities, building design and layout, hazardous material inventories, and service histories from previous calls.

Human Factors

Human factors play an important role in emergency responder safety and health. As data collection and manipulation capabilities increase, limitations in knowledge management, or the ability of people to effectively utilize available information, can impact responder safety in some cases. Commonly cited examples include underutilization of mobile data terminals and the inability to use or correctly interpret readings from environmental hazard monitors.

Another critical human factor is adoption of safety practices to mitigate day-to-day injuries, such as a sprain from a fall. Several agencies are addressing these hazards with standard approaches such as offering physical fitness classes, maintaining a safe environment in fire stations, and issuing properly fitting clothing and supportive footwear.

Tradition and culture also affect emergency responder safety. A common example is a preference for a certain style of fire helmet: Despite their substantial weight and higher cost, many firefighters prefer the appearance of traditional-style helmets with large brims. Another cultural aspect that may impact safety is the fraternal and often voluntary nature of the profession, which can temper enforcement of safety practices. In this regard, many participants pointed to the more stringent standards used by specialized units such as hazmat or urban search-and-rescue teams. Finally, tradition may hinder the adoption of safety and health innovations. Decisions on whether to accept new technologies or even simply to change brands or suppliers are deeply rooted in tradition.

PROCUREMENT AND LOGISTICS OF PROTECTIVE TECHNOLOGIES

Decisions on how PPTs are identified, acquired, and used in the field vary significantly, as was noted by many participants. Many issues and concerns were raised on the procurement and logistics of protective technologies that have implications for PPT research and development needs.

Personal Protective Technology Standards and Performance Evaluation

A critical concern for most departments was their getting adequate information to guide technology acquisitions. Participants indicated that few emergency response agencies have the resources or capabilities to conduct formal risk assessments to guide these acquisitions. As such, many departments choose protective technology based on supplier relationships. While design and performance standards assure a basic level of functionality and protection, distin-

guishing among the large variety of certified gear within each equipment class is not a straightforward process.

Consequently, most responder organizations must resort to informal, ad hoc PPT evaluation and information gathering and analysis because they lack access to reliable public sources on PPT performance that would inform their procurement decisions. In response to these problems, many participants strongly advocated implementing objective, third-party assessments to help guide them in their PPT evaluations and decisionmaking.

Storage and Maintenance

As emergency responders have acquired greater amounts of protective equipment, storerooms, vehicles, and people have become increasingly crowded and burdened. An individual can carry only so much gear. Squad car trunks are getting full. EMS vehicles have limited storage space. Many communities have purchased dedicated disaster response vehicles or trailers, and many have created supplemental equipment caches, but these measures raise questions about how rapidly such equipment will be fielded and who will have access to it.

As emergency response organizations acquire greater amounts of gear, their equipment maintenance and reliability needs are also increasing. Many emergency responders mentioned the strain that meeting these needs places on a department. Firefighters expressed concern over their departments' ability to ensure the integrity of turnouts (moisture barriers in particular) and other gear after extensive use. Several fire and police departments as well as PPT manufacturers felt that passive integrity monitors, such as indicators that change color as material properties change, would be a valuable addition to protective equipment. Along with the availability of sophisticated environmental monitoring and other electronic equipment comes the need for technical expertise and resources to maintain that equipment.

Universal Versus Tailored Personal Protective Technology

The role of emergency responders continues to expand as does the ability of emergency responders to evaluate site-specific hazards. Thus, several participants claimed, opportunities exist to improve safety by selecting protection options that are based on the specific situation. However, such options are currently quite limited.

The standard in the fire service is universal protection—a single ensemble designed to protect against all anticipated hazards. Such an ensemble is opti-

mized for structural fires and may not provide the best protection for the range of other situations firefighters encounter, such as vehicle accidents or medical calls.

Arguments against tailored protection include the simplicity that a single ensemble affords, uncertainties about the actual hazards, and the time, cost, and energy involved in supporting several types of protective clothing. Risk-specific protection is beginning to emerge: Protective clothing standards for urban search-and-rescue and emergency medical response ensembles recently have been introduced.

Interoperability

A final logistics issue concerns mutual aid⁵ agreements between jurisdictions and the interoperability of protective equipment. Interoperability of protective equipment may be critical at large incidents, as was the case with respirators at the World Trade Center in September 2001. Mutual aid agreements between jurisdictions typically address incident management, training, and technical capabilities, but protection is rarely included in this list. Major barriers to PPT coordination in the emergency responder community include incompatibilities in funding cycles, equipment replacement cycles, and purchasing power; tradition and well-established vendor relationships that hinder change; and the absence of procedures for accomplishing PPT coordination easily.

PUTTING COMMUNITY VIEWS TO WORK

A number of issues emerged from RAND's discussions with participants that have important implications for improving the protection of emergency responders. These issues generally can be divided between two areas: (1) priority areas for improving equipment and practices and (2) broader policy issues that warrant further research, analysis, and discussion. The priority areas are relatively straightforward and are, for the most part, consensus concerns within the responder community that were raised directly by the discussion participants. Many of the policy issues, on the other hand, are complex and pose challenging questions. These issues emerged indirectly from the community discussions, and most are marked by fundamental differences of opinion within the community. These issues are summarized in Tables S.1 and S.2. In several cases, these concerns are actively being addressed by government agencies and other organizations concerned with emergency responder safety.

⁵A *mutual aid* response is one in which more than one department participates.

Table S.1
Personal Protection Priorities and Recommendations Raised by the Emergency Responder Community

Personal Protection Priorities	Specific Recommendations
Reduce physical stress and improve comfort	<ul style="list-style-type: none"> • Improve garment breathability • Reduce equipment weight • Ensure consistent and appropriate sizing of components • Enhance ergonomic characteristics
Improve communications	<ul style="list-style-type: none"> • Make radio systems interoperable • Improve communications capabilities with SCBA • Improve radio design to allow hands-free use and use with gloves
Upgrade communicable disease protection	<ul style="list-style-type: none"> • Increase protective equipment options for EMS personnel and police
Develop practical respiratory and chemical protection equipment and guidelines for first responders	<ul style="list-style-type: none"> • Improve the chemical and biological protection of garments and respirators • Design protective equipment such that it minimizes interference with responder activities • Require more chemical/biological hazard training
Improve PPT standby performance	<ul style="list-style-type: none"> • Develop integrity monitoring and service-life monitoring technologies • Enhance compactness and portability of protective equipment • Address logistical complications • Reduce protective equipment maintenance complexity and cost
Expand training and education	<ul style="list-style-type: none"> • Require more training on sophisticated protective equipment • Reduce complexity of new equipment
Benchmark best safety practices	<ul style="list-style-type: none"> • Study and benchmark safety practices, particularly for EMS and police • Study and benchmark PPT enforcement practices

Table S.2**Key Policy Areas and Issues Raised by the Emergency Responder Community**

Policy Areas	Specific Issues
PPT research and development	<ul style="list-style-type: none"> • Research should be more strategic and multidimensional, including more fundamental, long-term research • Greater emphasis on ensembles is needed • R&D should address response activity rather than services • Decentralized market limiting innovation and purchasing power should be addressed
Discretion in personal protection decisionmaking	<ul style="list-style-type: none"> • Expanding role of emergency responders and improved hazard assessment warrant increased attention to activity-specific tailoring of protection
PPT standards for emergency medical services and law enforcement	<ul style="list-style-type: none"> • EMS and police communities need dedicated personal protection, safety, and standardization efforts
PPT performance assessment	<ul style="list-style-type: none"> • Reliable and objective equipment performance assessments need to be developed
PPT standardization and interoperability	<ul style="list-style-type: none"> • Mutual-aid agreements and extended operations should be facilitated by enhanced standardization and interoperability
The role of risk in emergency response	<ul style="list-style-type: none"> • Examine emergency responders' perceptions of and their responses to risks inherent in emergency response • Promote efforts to decrease risk through improved information management, clarified protocols, and improved equipment