First Responder Situational Awareness and Monitoring System

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Problem Statement

The leading cause of on-the-job fatalities among firefighters continues to be stress and other medical related issues usually resulting in heart attacks or other sudden cardiac events. Although the technology required to monitor the location and vitals of first responders during a call has existed for years, no one has successfully integrated all functions into a single, easy-to-use system. Such a system would allow rapid response to dynamically changing conditions on scene, alerting necessary personnel to the impending peril of fellow first responders, and providing for emergency extraction sooner than is currently possible. This is no trivial task, as it requires a highly reliable and easy-to-use system, both for first responders and coordinating personnel. As the average air supply available to firefighters is approximately 30 minutes and the low air alert occurs when 33% of the available air remains, a quick and coordinated response in the event of emergency is critical.

Such systems have been prototyped, but none satisfy all of our requirements together, and none provide the ability to enhance what each first responder sees, through the use of thermal imaging systems. As technology is always changing, a highly open and extensible software system is preferable, if not a requirement.
History of Firefighter Personal Safety Devices

Firefighter Personal Safety Devices or PSDs are very important to today's firefighters. In 1863, James Braidwood invented a breathing apparatus which is credited as being the first breathing apparatus for firefighters. Air was pumped from bellows through a hose and into a mask. It was dubbed the "Smoke mask." It was rarely used because it was unreliable and bulky. During and after World War II, firefighters started to use gas masks, but these did not protect against carbon monoxide nor function in an oxygen-deficient environment. In 1945, Scott Aviation introduced the Scott Air Pack. This Self-Contained Breathing Apparatus or SCBA is now a very essential piece of firefighting gear because it provides important protection for the firefighter's lungs, respiratory tract, eyes, and face. The tank weighs about 30 pounds and can hold up to 30 minutes of air. It is worn on the firefighter's back and is connected to an airtight mask that fits securely on the firefighter's face.

The Personal Alert Safety System, or PASS, is the other very important piece of PSD. PASS is a small battery-operated box that has motion detectors attached all over it that are used to warn other firefighters that a fellow firefighter is in trouble. If the device does not detect any motion for 10 seconds, it sounds a low beep to warn the firefighter that it is about to activate. If the firefighter is alright, he can move so it does not sound a false alarm. However, if the firefighter is seriously injured or trapped, he will not be able to move so the device will then emit a 95 decibel alarm to notify the other firefighters that one of their brothers is in trouble. If the firefighter is lost or trapped, he can manually activate the system. It can easily be activated while wearing gloves and is made to be operational in flammable conditions. PASS was first introduced to the firefighters in 1982, when the National Fire Protection Association set the standards for them.

Lastly, handheld thermal imaging cameras are used to identify hot spots in an active environment and provide visual information in low visibility environments.
Research and Current Solutions

Four prominent systems that are currently on the market or in development are discussed here:

**WASP system**

WASP is a comprehensive vital monitoring and position tracking system designed specifically for firefighters. It includes an undergarment shirt with built-in physiologic monitors and a belt with TRX position tracking. The TRX system works without GPS and builds a map of the scene as firefighters move about the building in real time.

**Motorola Next Generation Fireground Communications**

Motorola envisioned a high-tech firefighter suit which is part of a prototype concept called Next Generation Fireground Communications. It incorporates a host of wearable technologies including a helmet-mounted camera, a heads-up display on the SCBA mask, and environmental sensor, a wearable strap that monitors vital signs, indoor location tracking, and a rugged radio system. This system is not yet commercially available.

**Physiological Health Assessment System for Emergency Responders (PHASER)**

The PHASER system was developed by UCLA under the U.S. Department of Homeland Security, Science and Technology Directorate. The team has developed PHASER-net, which supports a low-cost networked system for individualized emergency responder physiological monitoring and risk mitigation. It utilizes wireless physiological monitors and leverages low cost durable smart phone platforms for secure data acquisition, processing, and interaction with incident commanders. The data is then uploaded from smartphones to a secure portal where archived data can be viewed.

**Geospatial Location Accountability and Navigation System (GLASNER)**

This system specializes in location tracking of first responders in varied environments. It provides both a 2D and 3D view of the structure superimposed with past and previous locations of first responders. This allows an incident commander to track personnel and be aware of potential dangers in their path. This system is accurate up to 3 meters in non-GPS environments and allows for 2-way audio communication.
Objectives, Goals, and Relevance to Quality of Life

The project's main goals are to reduce firefighter injuries on the job, and improve situational awareness, and therefore response effectiveness. According to the U.S. Fire Administration (USFA), 304 firefighters died while on the job. Most of these incidents occurred during structure fires. The top four causes of fatality were sudden cardiac events, asphyxiation, trauma, and burns. Though never fully preventable, many of these situations could have been avoided with improved monitoring of first responders and the environment they were in.

In a typical fire-related emergency, many of the first responders' physical senses are removed or greatly hindered. Sense of smell is removed by the SCBA gear. Sense of touch is removed by the heat protective gear. Vision is likely obscured due to smoke and debris. Providing information to personnel to supplement this sensory deprivation can help in the avoidance or early detection of dangerous situations. Hands-free thermal imaging and external temperature monitoring effectively restore two of the missing senses. Other pertinent information would include, but is not limited to vital signs monitoring such as personal temperature, heart-rate, hydration, and oxygen saturation levels.

Some or all of this information could be made available to individual team members as well as the incident commander and/or safety officer.
Functional Requirements

There are four main functional requirements as outlined below:

- Capture and communicate information about the environment to include, but not necessarily limited to the temperature.
- Provide information about the location of first responders relative to their environment to assist with timely emergency response and extraction.
- Allow individual to be able to access thermal imaging data on a hands-free display that can toggled on and off.
- Aggregate information in an easy to interpret format that can be clearly displayed on a reasonably sized tablet or other portable device.

The most important piece of environmental data is the temperature of the response area. The amount of time since the temperature was monitored is also of potential relevance. Potentially useful related information would be the relative air quality of the monitored environment. This information should be available to the individual on location at a minimum, and could also be useful to a team member formulating a secondary retrieval/extraction plan.

Should the rescue or extraction of a team member be necessary, locating them in an active environment as soon as possible is of tantamount importance. Providing accurate information about location of team members to other team members as well as to an external coordinator can dramatically improve response times. Extraction personal should be able to determine how far away a team member is, as well as their relative elevation.

Lack of visibility is possibly the greatest deterrent and hazard faced within an active environment. Being able to move thermal imaging to a hands free system would greatly improve team member safety and
decrease response times. Being able to toggle such a display on and off would allow the information to be present when relevant and eliminated as a distraction when not.

Any information collected has to be displayed in a manner that can be accessed and interpreted at a glance by all interested personnel. The data collected and made available should be configurable to be relevant to the individual team member's role and responsibilities. I.e.: the information needed by a team member entering an active site for fire suppression is not necessarily the same as the information relative to a site coordinator. The user interface, although needing to be customizable, should be easy to read and present information in an intuitive and consistent manner. Our previous experience leads us to believe that decentralized portable monitoring would have more practical use than a single centralized monitor.

Any system also needs to be relatively easy to use. It should place minimal additional encumbrance burdens on team members and provide relevant data in a timely and easy to interpret manner. Even the most sophisticated system is useless if it is not used.

Lastly, the more modular and scalable a system is, the easier is it will be to budget for and integrate into an operational plan.
User Profile and Deployment Environment

Two levels of monitoring should be made available. The first being information relevant to individual first responders such as individualized thermal imaging and vital signs monitoring. The second is aggregate information such as team member location within a structure, the temperature mapping of the structure, and vital signs of individual team members. This collected information should be made available to incident commanders and safety officers.

We imagine two portable interfaces that would cater to each officer separately, but that could be toggled or customized dynamically. The system will deployed in a variety of environments and as such needs to be rugged and waterproof. Components being brought into a fire need to be highly heat and smoke resistant. They will also need a significant battery life and/or be able to be recharged using existing facilities.

Training must also be provided on the use and care of all system components.
Future Plans and Expansion

We discussed the system being used for keeping a history of vital signs for each first responder from scene to scene. It has been brought to our attention however that such history would require data storage and maintenance that we are not currently interested in. It may be desirable to revisit this at a later date however.

A study by John Hopkins University \textsuperscript{viii} on heart attacks among firefighters found that although extreme environments and high stress may be contributing factors to sudden cardiac incidents, these events occur almost exclusively among firefighters with underlying heart disease. This study concludes that the key for prevention of such outcomes is to identify those firefighters that are at risk proactively.

In accordance with this goal, we would also like to consider tracking data about team members overall health.

\textsuperscript{i} *Firefighter Fatalities in the United States 2013*, NFPA, Rita F. Fahy, Paul R. LeBlanc and Joseph Molis, June 2014
\textsuperscript{ii} U.S. Firefighter Fatalities Due to Sudden Cardiac Death, 1996-2004, NFPA, Rita F. Fahy, June 2005
\textsuperscript{iii} NFPA 1981 2013 revision
\textsuperscript{iv} http://www.trxsystems.com/indoor-geolocation-solutions/
v http://motorolasolutions.com/promo/publicsafety/fire-ground-solutions.html
vi http://phaser.med.ucla.edu
vii http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6236870
viii http://ncbi.nlm.nih.gov/pmc/articles/PMC3378796/