2009 BFRL Project Description

Project Title: Emergency Responder and Occupant Locator Technology

Date Revised: 09/15/2008

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BFRL Program: Advanced Fire Service Technologies

Objective: To provide performance metrics for non-line-of-sight localization of emergency responders within buildings using UWB systems and create a library of building material properties that will enable the development of 3D tracking systems for emergency responders. This effort will also develop and demonstrate technology to capture and analyze cellular phone signals in order to provide emergency responders with a real-time, on-site estimate of building occupancy during emergencies.

Problem:

What is the problem? The fire service has several priorities upon arrival at a fire scene: rescue of building occupants, property protection, and fire suppression. In order to prioritize the deployment of limited resources, an incident commander requires accurate and reliable information about the presence or absence of occupants. If an incident commander can more effectively track the location of emergency responder teams working within and in the vicinity of buildings, there would be a significant reduction in fire fighter and civilian fatalities as well important decreases in fire property losses[1,2,3]. The overriding difficulty is that today's locator technology does not provide reliable communication between emergency response teams, occupants, and incident commanders.

Why is it hard to solve? Traditional technologies suffer from their ability to communicate through concrete and steel structures, and standard test methods and protocols are unavailable for manufacturers to evaluate new technologies or to demonstrate the value of hardware/software improvements to the emergency service providers. Previously, systems proposed to be installed to track the movement of occupants inside buildings have met with substantial objections from the perspective of initial cost, maintenance, as well as the privacy concerns of the occupants.

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[1] Duckworth, R. J., "Report on participation in the IAFF John Redmond Foundation Symposium Health and Safety for the Professional Fire Fighter", WPI/Foster Miller Inc/Globe Mfg, October, 2007.
[2] Wong, J., and Robinson, C., "Urban Search and Rescue Technology Needs: Identification of Needs", Document No. 20771, Dept. of Justice, November, 2004.
[3] 17% of firefighters fatalities reported so far in 2008 have listed as the cause of death "*Caught or Trapped*" (https://www.usfa.dhs.gov/fireservice/fatalities/).

How is it solved today, and by whom? NIST began to investigate UWB methods for tracking the movement of objects inside buildings as early as 1994. This program initially investigated time-of-flight through-wall tracking in the 0.5 to 2 GHz regime (which includes most cell phones) and then later extended the research to include all frequencies between 0.5 to 8 GHz. In FY08, NIST researchers in the Time Domain Fields Group (EEEL), working in support of BFRL, have extended those initial experiments to initiate the development of a library of building material transmission data. The problem of occupant enumeration is currently unresolved for emergency responders. Large buildings, such as high-rise or large footprint construction, represent particular problems for incident management.

Why NIST? This project fits the BFRL mission and vision. It anticipates and meets the need to develop measurement tools to evaluate locator technology, thus improving the safety and effectiveness of fire fighting. By providing the measurement science to improve safety for the fire service, this project is well aligned with the BFRL strategic priority of Measurement Science for Innovative Fire Protection, as well as BFRL's core compentency in fire protection and reducing fire spread within buildings and communities. BFRL has the ability to provide the knowledge through measurement science of the use of this solution-enabling tool to the fire service worldwide.

Approach:

What is the new technical idea? This effort extends research already underway to examine the capabilities and limitations of different technologies in a number of different scenarios. Each of the existing technologies has limitations, so currently no system based on a single technology appears to address all scenarios and conditions. Combinations of technologies, such as UWB and RFID or ad-hoc networks and RFID, will likely be necessary to allow continuous 3-d tracking of teams in wood, steel, and concrete structures.

Particular attention will be paid to the types and sizes of structures chosen for testing the performance of locator technologies. Structure types identified in NFPA 5000 (concrete, masonry, wood, steel, etc…) will be used initially to determine the feasibility of scaling down enclosures to a size suitable for laboratory or bench measurements. Measurements of signal penetration through various structure types will be compared with scaled enclosures to ensure that the scaled enclosures retain a meaningful challenge to the performance of locator devices. Performance metrics will be designed to encompass a range of structure types that can be efficiently measured in a laboratory.

Personal cellular phone usage is nearly omnipresent in the urban setting. In order to connect to cellular towers, each phone emits a unique identification signal. Small antennae attached to fire department apparatus can read the cellular phone signals. By combining at least three signals, the source location for the cellular emission may be triangulated in space and tracked temporally. As fire department protocols already require staging of apparatus on multiple sides of a building, the cellular signals may be readily identified as originating from inside or outside the building during an emergency. The incident commander (IC) will be provided a real-time estimate of the number of people remaining inside the building as a function

of time. Likely, the information will be reduced to simplified presentation in order to ease interpretation by the IC.

Why can we succeed now? Personnel locator devices are currently a very active area of research because a) no one has yet solved the problem of providing reliable communication between incident command and teams working within buildings, and b) locating emergency responders within structures as well as building occupants is vital to the reduction of loss of life and property. Without meaningful performance metrics and test methods in place to prove the value of prospective locator systems, unreliable products may be sold to unknowing first responders while perfectly useful systems may not realize their full potential. Cell phone ubiquity and cellular technology have reached a critical mass such that the usefulness of the technology may be utilized with sufficiently reliable results.

What is the research plan? New locator technology, developed for military and security applications, will be tested in FY09 and shows promise for significantly improved performance, and lessons learned from previous OLES research will be used in the development of standard test methods for UWB tracking systems. The technology used for assessing the quality of locator system signals will be developed and tested in FY09, while a parallel effort will be made to determine the most appropriate structure types and enclosure sizes for laboratory-scale performance testing. In FY10, these two branches of research will combine to implement signal analysis of locator devices in realistic environments.

With respect to building occupants, in FY2009 the research team will complete three major tasks: first, develop and demonstrate the antennae system to read the cellular signals in a laboratory environment, including a patent application if successful; second, develop and demonstrate the signal analysis which will enumerate and locate multiple cellular signals; and third, in cooperation with the fire service, develop a user interface to display the results to an incident commander. In FY2010, the research team, in cooperation with a county fire department, will deploy a prototype system to real fire incidents in order to assess the utility and accuracy of the system.

Recent Results:

Proof-of-concept demonstration of tracking first responders in a residential structure using a commercially available UWB system. Lessons learned from OLES research was used in the development of standard test methods for UWB tracking systems.

Completed initial experiments in determining the reflection and transmission measurements of building materials using a free field measurement system.

Outcome: Developed methods of reprocessing the original NIST NLS data to extract dielectric constants of common construction materials. This work resulted in frequency-dependent dielectric and free space permittivity constants associated with the propagation of EM waves in the 0.5 to 8 GHz domain through common construction materials.

Outcome: Preliminary field experiments to document current performance of RF-based systems was completed. These results were also described to NFPA 1800 Committee and at the 2007 Precision Indoor Tracking of Emergency Responders Workshop at Worcester Polytechnic Institute.

Standards and Codes: Research that supports a standard on personnel locator devices was identified as one of the most important needs at a recent NFPA Research Division Steering Group meeting. The NFPA Technical Committee on Electronic Safety Equipment (FAE-ELS), of which Francine Amon is a member, will be ultimately responsible for a performance standard on emergency responder locator devices; however, work on this standard has not been formally assigned at this time.

Impact: Incident commanders that adopt technology enabling the estimation of the number of building occupants can quickly make decisions regarding their resources and fire attack strategy, potentially saving time, lives, and property.

Impact: Firefighter localization systems are of critical importance to the fire service; however, they are not reliable at this time. Performance metrics that evaluate their accuracy and robustness will be embraced both by users and industry.