Department of Homeland Security
Science and Technology Directorate
First Responders Group
National Urban Security Technology Laboratory

Firefighter Accountability and Proximity (FFAP) System

Operational Field Assessment Report

February 2017

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Executive Summary

On Friday, January 29, 2016, the National Urban Security Technology Laboratory (NUSTL) conducted an operational field assessment (OFA) of the firefighter accountability and proximity (FFAP) system in Butler, Pennsylvania, with members of the Herman Volunteer Fire Company.

The genesis of the FFAP occurred in May 2011, when members of the Los Angeles County Fire Department formalized a capability gap they had in regards to team integrity and accountability in the *Firefighter Accountability and Proximity System Operational Requirements Document.* Maintaining fire ground personnel accountability and proximity to the team leader or incident commander during structural firefighting operations was sub-optimal. As a result, the risk of firefighters becoming lost during chaotic operations was higher than desired. The time to locate and recover lost firefighters was also higher than desired. Increased situational awareness could reduce the time to locate and recover a downed firefighter. This could sometimes mean the difference between injury and death.

The requirements for FFAP have evolved since 2011 based on feedback during the development cycle from first responders across the nation. These first responders contributed as subject matter experts and represented the New York City Fire Department, Rockville Volunteer Fire Department of Maryland, Merrionette Park Fire Department and Waukegan Fire Department in Illinois, Colfax County Nebraska Fire Department and Herman Volunteer Fire Company of Pennsylvania. These changes were captured when the project was refocused to meet needs of small, rural departments in November 2014.

The OFA was conducted in two phases. The first phase allowed first responders to gain familiarization with the FFAP device, particularly its accuracy and range. The second phase allowed first responders to understand how the FFAP may be used to augment their concept of operations during structural fires and lost person recovery scenarios.

First responders found the technology increased their safety and ability to maintain better situational awareness with regards to their team members. First responders provided constructive suggestions with regards to hardware configuration and a user interface design they believed would improve upon the product.

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1 Introduction

A capability gap exists in maintaining fire ground personnel accountability and proximity (to the team leader) in structural firefighting operations. This has resulted in firefighters becoming lost or disoriented while searching for team members, thus imperiling their safety and that of their team members.

In May 2011, the Department of Homeland Security (DHS) Science and Technology Directorate (S&T) formalized this challenge, identified by fire service professionals from the Los Angeles County Fire Department, into an Operational Requirements Document (ORD). On January 23, 2013, TRX Systems, Inc. was awarded a contract to develop a Firefighter Accountability and Proximity (FFAP) system that would address this gap.

The FFAP's goal is to improve safety through earlier identification of firefighters who become lost or disoriented and to improve rescue response times through identification of firefighters who are closest to (or were last near) a lost or disoriented firefighter. Input from the Fire Department of New York, Rockville Volunteer Fire Department of Maryland and Herman Volunteer Fire Company of Pennsylvania were used to narrow the focus towards small suburban and rural fire departments.

1.1 Purpose

The purpose of this operational field assessment (OFA) was to gauge the FFAP system's suitability in its current state and, based on user evaluation, to determine its ability to be a viable solution for the first responder community.

1.2 Objective

The objectives of this OFA were to:

- Characterize operational performance parameters of the system;
- Assess and evaluate system performance in real life scenarios using trained first responders; and
- Identify key usability features of the FFAP system.

1.3 Requirements

DHS S&T published an ORD titled *"Firefighter Accountability and Proximity System Operational Requirements Document,"* in May 2011 based on input from the Los Angeles County Fire Department.

In April 2014, this project was refocused with the input of five first responder resource group subject matter experts. The conclusion was to have this technology focus on meeting the needs of rural and volunteer fire companies.

1.4 System Description

The FFAP, also known as the NEON Proximity, is intended to help firefighters account for each other by providing information on their distance from each other.

The system is comprised of two key pieces of hardware: the TRX proximity unit, which is meant to be worn or placed into the pockets of each firefighter (Figure 1); and the hand-held display (Figure 2). The TRX proximity unit uses a method known as “time of flight” to measure and report on the distances between itself and other TRX proximity units. A radio frequency signal is sent from a TRX proximity unit with a known speed to other TRX proximity units that are within its range. The time it takes to reach the receiving TRX proximity unit is recorded and used, along with the known speed, to calculate the distance of one TRX proximity unit to the other. The TRX proximity unit also uses ultra-wide band (UWB) technology, which allows for information to be transmitted over a large spectrum bandwidth, usually 500 MHz or greater. The UWB technology allowed for more accurate ranging and proved to be resistant to multipath propagation, a wireless telecommunications phenomena that can lead to a whole host of issues, such as poor quality signals or inaccurate readings of distance measurements.

Figure 1 - **TRX Proximity Unit - to be worn or carried by all members of fire team.**

The hand-held display is a Samsung Galaxy S5 smartphone encased in an Otterbox™ protective case, as seen in Figure 2. The display is intended to be carried by a team leader, a member of a rapid intervention team (RIT) or an incident commander who is outside the incident area. A TRX proximity unit is paired to the hand-held display via a Bluetooth® wireless connection. A software application on the phone will then display all the distances of the team members carrying TRX proximity units, relative only to the TRX proximity unit that is Bluetooth® paired to the hand-held display. Figure 3 illustrates how all of the TRX proximity units in the ad hoc network will only report their distance relative to the TRX proximity unit paired with the hand-held display.

Figure 2 - Handheld display carried with a paired TRX proximity unit by the team lead or incident commander.

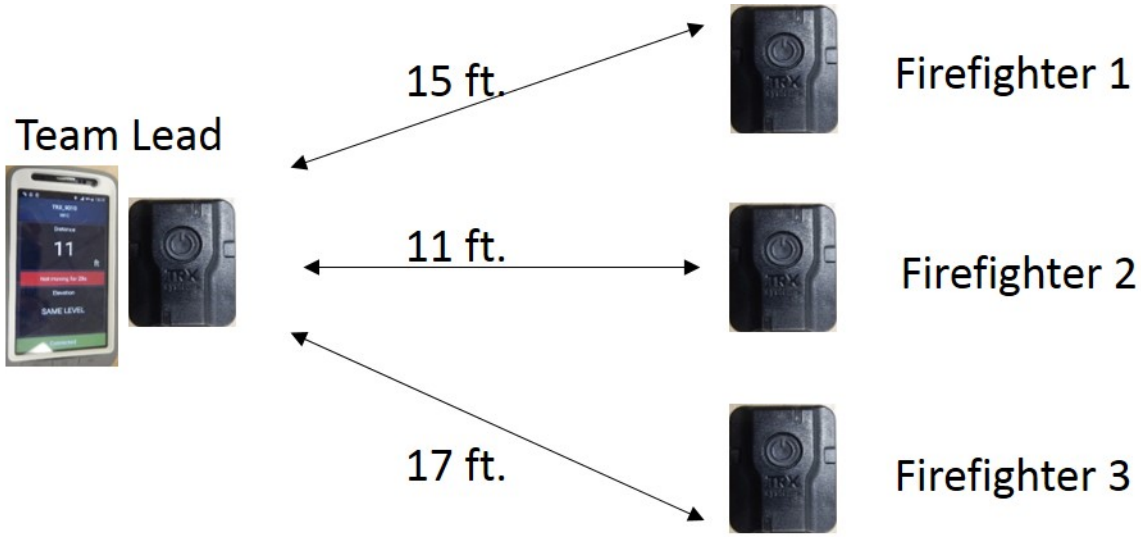

Figure 3 - The TRX proximity units indicate distance from team lead's sensor only, but still ping and send information through all sensors.

2 Operational Field Assessment Design

The OFA was conducted in two phases. The first phase was a line-of-sight walkout that allowed first responders to gain familiarization with the device, particularly its accuracy and range. The second phase simulated lost person recovery and allowed first responders to assess how the FFAP may be used to augment their concept of operations during structural fires and lost person recovery scenarios. These activities were preceded by a brief training session led by the technology developer.

2.1 Participants

Table 1 lists the OFA participants. Ten evaluators who tested and provided feedback on the FFAP system included nine firefighters from the Herman Volunteer Fire Company and one from the Rocky Grove Volunteer Fire Department.

Table 1 - Participants

Role	Organization
10 Evaluators	Herman Volunteer Fire Company
1 Evaluator	Rocky Grove Volunteer Fire Company
Test Site Host	Herman Volunteer Fire Company
Program Manager	DHS R-Tech
OFA Director	DHS NUSTL
Technology Developer	TRX Systems, Inc.
Photography	DHS CORE
DHS R-Tech Support/Data Collector	Teracore, Inc.

2.2 Phase 1 – Walkout and Familiarization

The goal of this phase was two-fold. First, it provided participants with an opportunity to gain further familiarity with the system before moving on towards a more complex, operations-based scenario. Second, it allowed participants and test facilitators to evaluate the accuracy of the system in reporting actual distances.

This procedure involved the use of four proximity sensors and two hand-held devices. Two proximity sensors were stationary and collocated with the hand-held display at a point we will call the “origin.” The other two proximity sensors were given to participants who walked along a straight path away from the origin, stopping periodically at pre-marked locations (20-foot intervals) to report their actual distances and record their observed distance readings on the hand-held display. Figure 4 below illustrates where the line-of-sight walkout was conducted. Distances were marked using traffic safety cones. There was a slight upward gradient in this location (see Figure 4). Figure 5 shows first responder participants and test facilitators at the origin recording FFAP reported and actual distances.

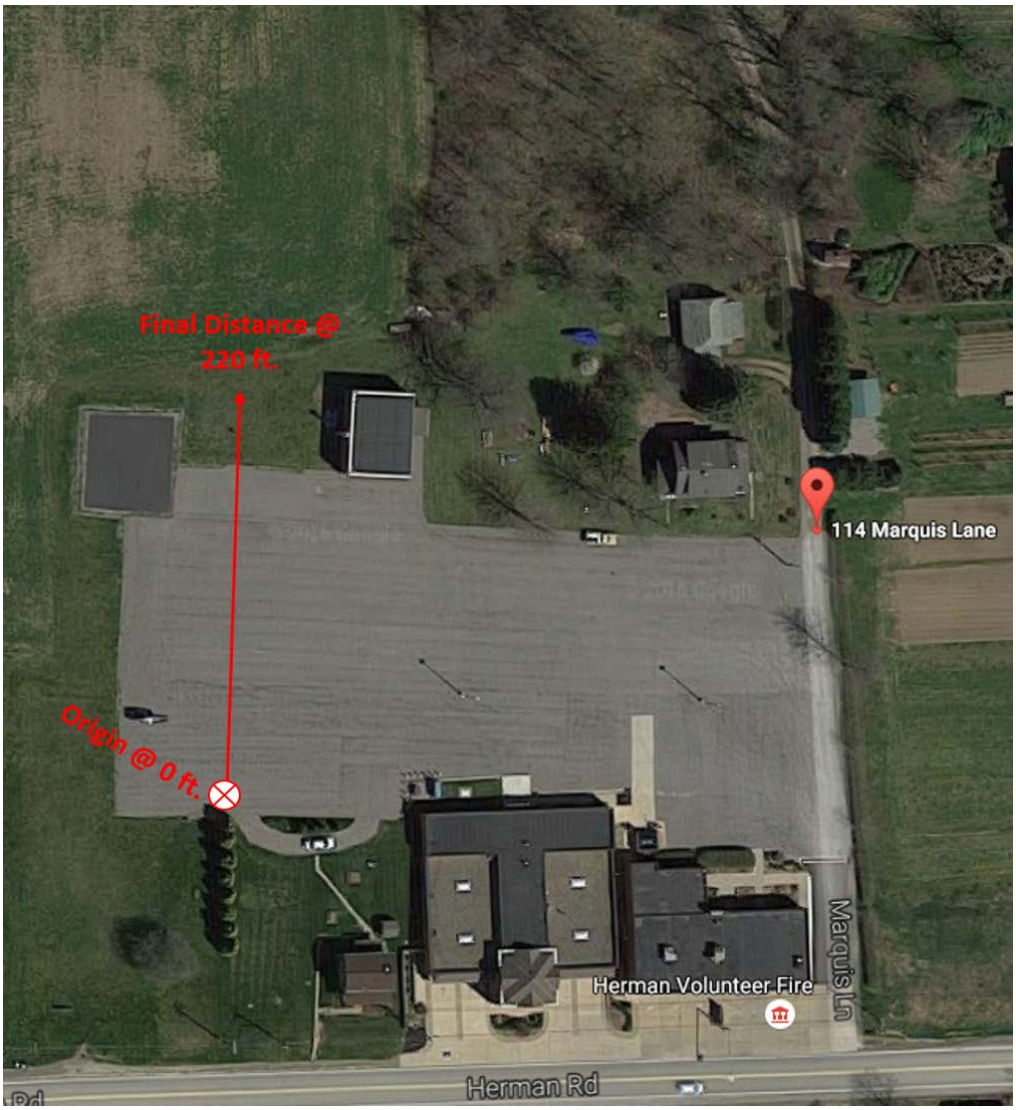

Figure 4 - Aerial view of where walkout was conducted.

Figure 5 - Participants and test facilitators at the origin point of the walkout.

2.3 Phase 2 – Lost Person Recovery

This phase was designed to help participants evaluate the FFAP system's ability to aid a RIT member in the search and recovery of a lost or downed firefighter. A single TRX proximity unit was hidden several times during the exercise in different rooms on the first floor of the Herman Volunteer Fire Company building. Participants, acting as a member of a RIT team and using a hand-held display and Bluetooth® linked TRX proximity unit, entered the structure and attempted to locate the hidden TRX proximity unit relying primarily on the FFAP system. This exercise was carried out six times by six different participants, with each person looking for a single, different hidden location.

3 Data Analysis

Data was collected by test facilitators in the form of observations, notes and a debrief session in which feedback was solicited from the first responder participants.

3.1 Phase 1 – Walkout and Familiarization

A total of four TRX proximity units were used for the walkout phase. At the origin, collocated with two hand-held displays, were the TRX proximity units designated with serial numbers 9038 and 901A. Two other TRX proximity units that were being walked along the straight line-of-sight path were designated by serial numbers 902F and 9008. TRX proximity unit 9038 (at the origin) was tracking the relative distance of TRX proximity unit 902F. TRX proximity unit 901A (at the origin) was tracking the relative distance of TRX proximity unit 9008. Please see Figure 6 for further illustration of where each TRX proximity unit was.

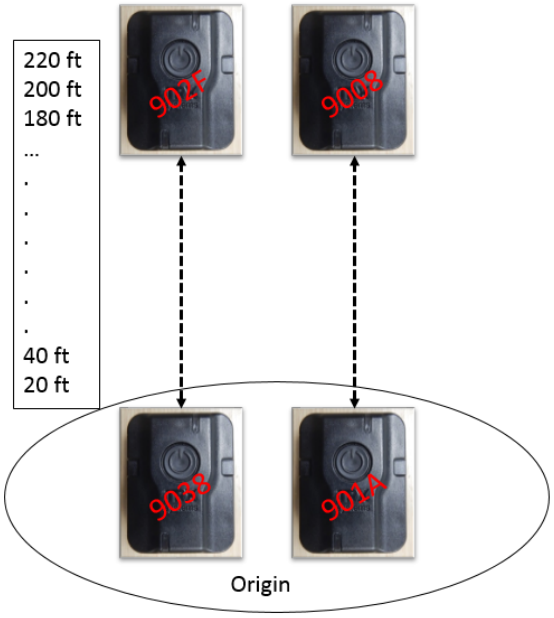

Figure 6 - Walkout phase equipment setup.

Relative distances reported by the hand-held mobile devices were recorded and shared with all participants to help them gain familiarity with the level of accuracy of the device. The results collected were compared to the actual distances. The following formulas were used to report (1) difference from actual distance and (2) average difference from actual distance. It should be noted that all differences in reported distances and actual distances were such that the FFAP system indicated the TRX proximity unit was always further away than the true distance.

(1) Difference from Actual Distance = |Actual Distance – Reported Distance|

(2) Average Difference from Actual Distance $= \frac{1}{n}\sum_{i=1}^{n} x_i$

a. n = number of samples; x_i = value of difference from actual distance at sample *i* of n

3.2 Phase 2 – Lost Person Recovery

Data collected from the Lost Person Recovery phase were qualitative and observational. Five participants were asked to locate TRX proximity unit 902F, which was hidden in three different times in different rooms on the first floor of the Herman volunteer fire company building. The rooms were an office, a conference room and a garage (see Figure 7). Participants started on the west side of the second floor. TRX proximity units 9009, 9038, 9008 and 901A were used to locate the hidden TRX proximity unit.

Figure 7 - During phase 2, a TRX proximity unit was hidden in different rooms and participants were asked to locate it using the FFAP system.

4 Results

Results from both phases of testing and a summary of user feedback captured during a debriefing session are reported in this section.

4.1 Phase 1 – Walkout and Familiarization Results

The results for Phase 1 can be seen below in Tables 2 and 3.

Table 2 - Actual distances between the TRX proximity units versus reported distances

Actual Distance (ft.)	Reported Distance (ft.)	
0	SN: 902F & 9038	SN: 9008 & 901A
20	24	23
40	42	41
60	66	63
80	83	82
100	103	102
120	122	122
140	143	142
160	162	162
180	182	182
220*	223	-

*We had planned to observe results only up to 180 ft.; however, we conducted one more record at the request of a participant at 220 ft. The manufacturer claimed the expected operating distance under line of sight circumstances was approximately 164 feet. The distance of 180 feet was chosen to assess the capability of the system at slightly beyond those limits.

Table 3 - The difference between the actual distance and reported distance of the TRX proximity units

Actual Distance (ft.)	Difference from Actual (ft.)	
0	SN: 902F & 9038	SN: 9008 & 901A
20	4	3
40	2	1
60	6	3
80	3	2
100	3	2
120	2	2
140	3	2
160	2	2
180	2	2
200	N/A	N/A
220	3	N/A

The overall average difference between the actual and reported distances among the four TRX proximity units evaluated is 2.6 ft.

4.2 Phase 2 – Lost Person Recovery Results

Observational data and qualitative user feedback were collected during this phase of the assessment. All participants were able to use the FFAP system to locate the hidden TRX proximity unit in a matter of seconds to minutes.

During this phase, participants became interested in understanding how the system performed in the vertical direction. They then used TRX proximity units with serial numbers 9008, 9038, and 901A while on the second floor of the Herman volunteer fire company building to locate and track TRX proximity unit 902F through the wooden floor below.

The comments and observations collected during this phase of the assessment have been grouped together with the comments and concerns discussed by participants during the debrief session; these can be found in section 4.3.

4.3 Observations, Comments and Feedback

This section contains a summary of the observations collected by data collectors, as well as direct comments and feedback from participating first responders during the entirety of the assessment, the majority of which was collected during a debrief session.

As with any new technology, the feedback was varied and full of ideas for improvements. Table 4 below attempts to group them into several broad categories.

Table 4 - Summary of participant feedback and observations

Comments on Graphical User Interface
A mapping feature that could be used by incident commanders is highly desirable so that a more visual component can be used to gain an understanding of where firefighters are in relation to each other.
If a mapping feature is not available, incorporating a sense of directionality towards the team member selected is very much desired. Firefighter participants understand that this could be computed mentally on their own based on the readings and direction they move in as they move about, but having the system constantly and automatically do it could save time and reduce errors in guessing directionality.
Under circumstances where many first responders are using the system, there is a desire for grouping people such that several members of a single team are represented only by a single entry on the user interface, such as that of the team lead.
Many participants stated they were more familiar with Apple's mobile operating system and suggested that Android devices may add to the learning curve involved with using the device properly.
If an incident command laptop or desktop version is to be created, it is desired that the incident commander has the ability to change the names and labels of different team members. Evaluators stated that it might not be a good idea for the hand-held devices, in this case Android-based mobile phones, be used by members of a fire team, such as the team lead; and instead that accountability and monitoring functions should be delegated to an incident commander or accountability officer who does not enter the structure or area of an incident.
Comments on Hardware
Participants commented that if the system were integrated into their self-contained breathing apparatus (SCBA) and required less user interaction, this would reduce the number of issues they might encounter with use of the system.
Participants commented that integrating FFAP's display into a hand-held thermal imager would be highly valuable to RIT members by combining range information with thermal imaging information, providing better situational awareness.
If the product is affordable, participants would consider buying both a stand-alone FFAP and one integrated into the SCBA system.
Participants found that the size of the system was appropriate, small and lightweight.
Participants stated the devices have to be extremely ruggedized because they will otherwise corrode from exposure to water, foam, dirt, etc.
There is a desire for a docking station (no wires) into which the TRX proximity units can be directly plugged. If a docking station is developed, firefighters also noted they would appreciate having customizable stations that include the same number of slots as units purchased so accounting for all devices after an incident can be performed quickly.
Participants were in agreement that the current battery life of four hours between charges is sufficient for their needs.

Other Comments on Use and Capability
There was a desire to get more consistent or better ranging capability through higher transmission power. There were several instances where the connection between two TRX proximity units ranging to each other was lost due to the structure's walls, floors and other barriers.
Participants noticed the TRX proximity units ranging to each other often lost connection signal when they were very close to each other, at distances of about three to six feet.
Concern was expressed over requiring firefighters to remember to launch another technology when they have so many others pieces of equipment to account for and are also busy preparing for the fire scene before they arrive. To that end, participants expressed a desire to only have the responsibility of turning on the FFAP, to have some automatic-on trigger independent from their own actions such as motion or integrating it with their SCBA so that it comes on with the SCBA unit.
Their expressed hope is that, with the system as it is, the team lead, incident commander or accountability officer (depending on each station's structure) would be responsible for pairing the TRX proximity unit to the Bluetooth® hand-held device before providing the individual devices to the firefighters.
Participants noted that the FFAP system can be applicable in three types of fire-fighting environments: structural, wildland and search & rescue (S&R), especially in rural areas. For wildland firefighting scenarios, testers mentioned that they do not often wear their SCBAs, which justifies their desire to have the FFAP system be offered as both an SCBA integrated product and independent product.
Participants commented that the FFAP system would be more likely used during S&R applications than wildland fires because during these scenarios, it is unlikely that firefighters will remain within visible range of each other.

5 Conclusion

The majority of evaluators stated the FFAP was useful and would further increase their safety and accountability. Their comments largely focused on how such a product could be further streamlined into their concept of operations and how certain standard operating procedures might be augmented to account for such a technology.

A debrief session was held after the completion of the experimentation activities. The majority of the discussion focused on how, and if, this technology could be integrated into hardware such as SCBAs and thermal imagers. Other aspects of the discussion focused on the best way to employ such a technology. First responder evaluators suggested the set-up and accountability of such a device might best be managed by an accountability officer or incident commander, to reduce the burden on the responding firefighter.

6 References

1. Firefighter Accountability and Proximity System, Operational Requirements Document (DHS S&T, May 2011).
2. Project Plan/Statement of Work for CCAT Prototype Development Grant (TRX Systems, Inc., January 2013).
3. Firefighter Accountability and Proximity Gap, Critical Design Review Meeting Report (DHS S&T, September 2013).
4. Use Case and Technical Requirements for Rural/Small Suburban Volunteer Firefighter Accountability and Proximity System (TRX Systems, Inc., February 2015).
5. Proximity/Honing System Development for Firefighters – Quarterly Progress Review (TRX Systems, Inc., August 2015).

7 Acronym List

DHS	-	Department of Homeland Security
FFAP	-	Firefighter Accountability and Proximity
NUSTL	-	National Urban Security Technology Laboratory
OFA	-	Operational Field Assessment
ORD	-	Operational Requirements Document
RIT	-	Rapid Intervention Team
R-Tech	-	First Responders Technology Program
SCBA	-	Self-Contained Breathing Apparatus
S&T	-	Science and Technology Directorate
S&R	-	Search and Rescue