



TSM™ Tactical Radios for Urban and Subterranean Environments

Experimentation Report

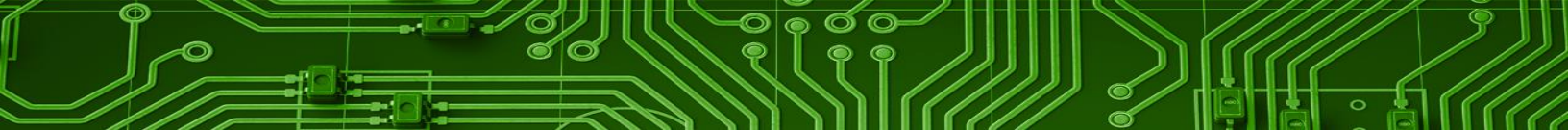
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**Homeland
Security**

Science and Technology





The *TSM™ Tactical Radios for Urban and Subterranean Environments Experimentation Report* was prepared by the National Urban Security Technology Laboratory, U.S. Department of Homeland Security, Science and Technology Directorate.

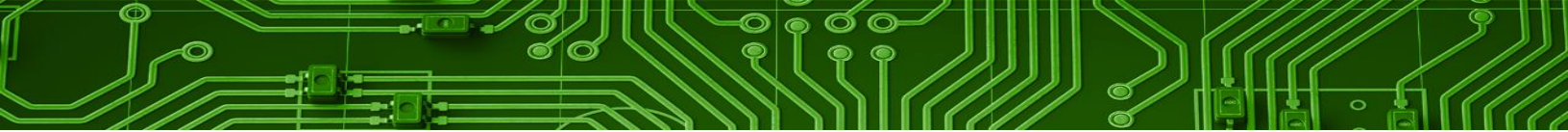
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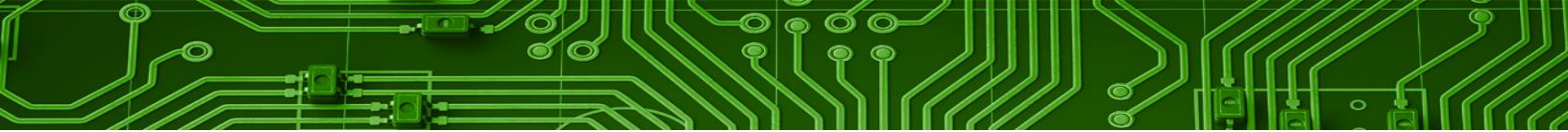
FOREWORD

The U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) Urban Operational Experimentation (OpEx)—hosted by the National Urban Security Technology Laboratory (NUSTL)—provides first responders with the opportunity to experiment with new and emerging technologies in realistic, urban settings. This event combines demonstrations of leading-edge technologies with application-based field assessments throughout the New York City metropolitan area.

NUSTL hosts the S&T Urban OpEx with participation from a broad range of federal, state, local, academic and private sector partners. The S&T Urban OpEx presents an important opportunity for DHS to gain a greater understanding of the operational needs and requirements of local first responders, while enabling first responder agencies to assess new technologies.

Capability gaps and potential technologies are reviewed with New York City first responder agencies to ensure the S&T Urban OpEx best addresses local responders' needs, interests and priorities, and benefits the homeland security enterprise as a whole. Participating first responders train on and experiment with technologies they have identified as possible solutions to meet priority capability gaps. Participants are also in the unique position to influence the development of new technologies and provide recommendations for future DHS S&T investments through their field technology experiments.

For more information on S&T's Urban OpEx or to view published Urban OpEx reports, visit www.dhs.gov/science-and-technology/frg-publications.



POINT OF CONTACT

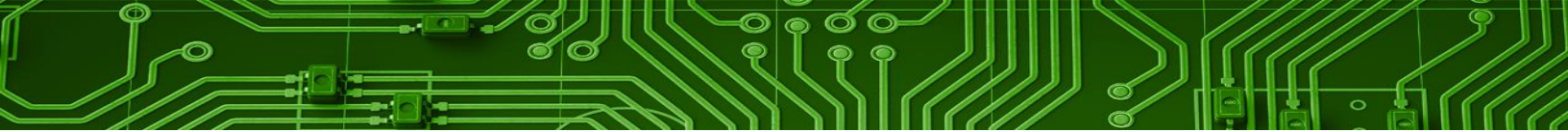
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EXECUTIVE SUMMARY

The TW-400 CUB TSM™ tactical radio, developed by TrellisWare Technologies Inc., underwent Urban Operational Experimentation (OpEx) on January 26, 2017, by the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) National Urban Security Technology Laboratory (NUSTL). NUSTL hosts Urban OpEx to introduce new technologies to first responders corresponding to their identified needs, and to provide feedback to technology developers—while sharing results with the national first responder community.

The TW-400 CUB TSM is a handheld radio that forms an ad-hoc network with nearby radios such that each can collaboratively receive and transmit voice, data or video, allowing communications to “hop” from radio to radio to extend communication coverage and range. This provides a potential solution to a responder-identified need for technologies that enhance the ability to communicate information from the scene of an incident that is Global Positioning System (GPS)-denied and impedes radio frequency (RF) signals (such as tunnels and underground subway systems) to colleagues and incident commanders who may or may not also be in such environments.

The experiment was carried out in the West 4th Street subway station in New York City. This was the same site as a National Institute of Standards and Technology study that characterized radio signal attenuation (or path loss) from the street level to each underground level. The experiment was designed to simulate a response situation where an incident commander needs to communicate with field personnel deploying into such an environment.

During the experiment, six first responder evaluators from local and national agencies were equipped with TW-400 CUB TSM radios. One evaluator remained at the street-level entrance to the subway station acting as an incident commander, while the remaining five entered the station and performed radio checks back to the incident commander at predetermined points. Whenever the communication failed, an evaluator would move back into range with their radio and remain there as a repeater node, allowing the other evaluators to proceed farther. When the evaluators completed radio checks at all of the predetermined points, they experimented with communicating while moving freely about the station.

The TW-400 CUB TSM radios successfully provided communication coverage throughout the subway station with the use of two radio node links to the incident commander. Within the station, radio network strength varied based on the fixed environment and on transient conditions, such as the presence of trains in the station or of people filling an exit staircase. Video was successfully transmitted with some instances of freezing or pixilation. Outside of the station, the TW-400 CUB TSM radios demonstrated a range of at least a half mile through the city.

Evaluators commented positively on the TW-400 CUB TSM radio technology, communication range, voice quality, video-streaming and additional capabilities of the technology’s software application. Negative comments included the radio’s relatively large size, lack of an integrated microphone and the inability to hear more than one speaker at a time. Evaluators saw great value in the technology as a force multiplier to augment operations with limited personnel resources; for example, during ship inspections and port operations. Overall, the experiment was successful in demonstrating the usability of the radios in difficult, urban communications environments, and in consideration of the technology for different mission scenarios.

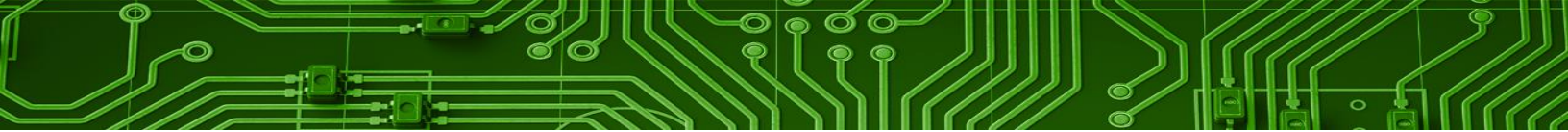


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1.0 INTRODUCTION

Reliable communications and situational awareness are priorities for first responders during both normal operations and in emergency conditions. Urban environments pose particular challenges to communication and personnel tracking because dense concrete buildings, subterranean subway tunnels and/or urban canyons can block or attenuate radio frequency (RF) and other wireless communications signals. In addition, during man-made or natural disasters, infrastructure such as cellular towers could become damaged or destroyed, further hampering communications.

Mobile ad hoc networks (MANET) are an emerging wireless networking technology comprised of mobile nodes that create a self-forming and self-healing mesh network for communications without the need for fixed infrastructure. Mobile nodes collaboratively receive and retransmit data, allowing communications to “hop” from radio to radio within a challenging RF environment to reach others within and outside that environment (Figure 1-1). The TrellisWare Technologies Inc. TW-400 CUB TSM™ is a MANET radio that utilizes a specialized waveform and specific techniques in the radio’s physical and networking layers. It can transmit voice, position location information and video over a mesh network in environments where RF signals are impeded and Global Positioning System (GPS) signals are denied.

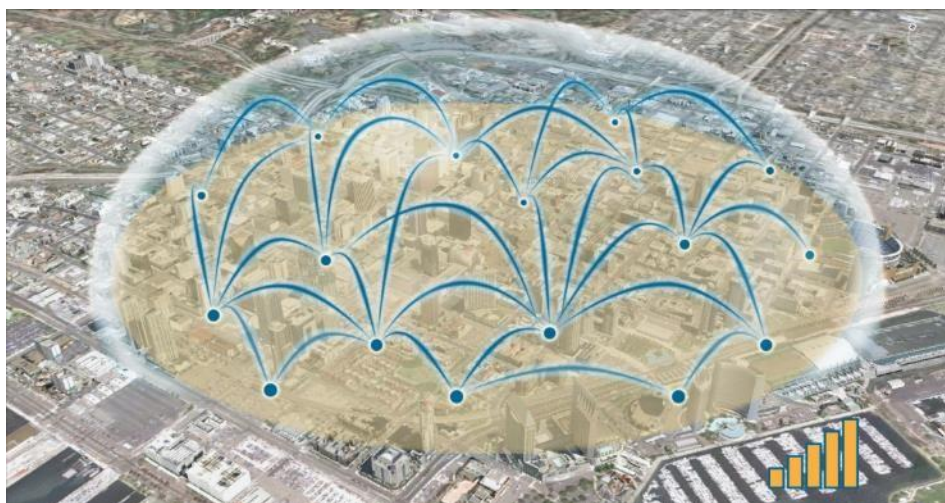


Figure 1-1 Notional Representation of MANET System with Multiple Radios as Nodes

Image courtesy of TrellisWare Technologies Inc.

On January 26, 2017, the TW-400 CUB TSM radio was assessed during the Urban Operational Experimentation (OpEx) event hosted by the Department of Homeland Security (DHS) Science and Technology Directorate’s (S&T) National Urban Security Technology Laboratory (NUSTL). The Urban OpEx was planned in collaboration with the New York City Fire Department (FDNY), New York City Emergency Management, New York City Police Department (NYPD), Port Authority of New York and New Jersey, and the Metropolitan Transit Authority’s (MTA’s) New York City Transit (NYCT). Subject matter experts assisted in selecting technologies, planning scenarios and arranging experiment venues. During the Urban OpEx, local and national first responders experimented with the TSM radios in a subterranean, multi-level subway station and provided their feedback and observations.

NUSTL gathered input from subject matter experts across the participating agencies and conducted a thorough technology selection process to establish three topic areas (Table 1-1) for experimentation at the Urban OpEx.

Table 1-1 Urban OpEx Technology Focus Areas

Topic Area	Description
Incident Management System	Emergency Data Exchange Language (EDXL)-compliant incident management software, for large and cross-jurisdictional emergency management, that allows for data to readily be received and shared with other EDXL-compliant software.
Communications and Tracking in Subterranean Environments	Technology solutions that enhance a first responder's ability to communicate voice, data and location information from an incident area that is GPS-denied and impedes RF signals (e.g., tunnels and underground subway systems) to other colleagues and incident commanders who may or may not also be in such environments.
Video Content Analysis and Video Analytics	Mobile and deployable technology solutions that aid law enforcement in threat detection, including but not limited to: anomaly detection (e.g., left behind bags), behavior threat detection (e.g., crimes in progress, people in need of assistance) and facial recognition.

1.1 PURPOSE

The purpose of the Urban OpEx was to evaluate the TW-400 CUB TSM MANET radios as an option for first responders in urban, GPS-denied, RF-challenged communications environments. The Urban OpEx:

- Exposed first responders to emerging technology in an operationally relevant environment;
- Provided first responders with an opportunity to offer feedback directly to product developers; and
- Gathered technological data and first responder feedback on an emerging technology for sharing such information with the national first responder community through the development of detailed experimentation reports.

1.2 OBJECTIVE

This experimentation was designed to allow first responders to use the TW-400 CUB TSM radios in operational settings, and to offer feedback and suggestions to the technology developer that could be used to enhance the product capabilities for first responder operations.

1.3 RESPONDER CAPABILITY NEED

Prior to Urban OpEx, local first responders were canvassed for input on capability gaps that could be solved with technological solutions and technology areas of interest. Input was used to develop topics, including “communications and tracking in subterranean environments,” defined as “technology solutions that enhance a first responder’s ability to communicate voice, data and location information from an incident area that is GPS-denied and impedes RF signals (such as tunnels and underground subway systems) to other colleagues and incident commanders who may or may not also be in such environments.”

Technologies received in response to a U.S. government-issued request for information that met this objective, such as the TW-400 CUB TSM radios, were considered for inclusion in Urban OpEx.

1.4 EQUIPMENT DESCRIPTION

The TW-400 CUB TSM radio (Figure 1-2) is a handheld radio with 2-watt transmit power, operating in the government-exclusive 1775-1815 megahertz (MHz) and 2200-2250 MHz frequency bands. It employs a proprietary waveform (TSM) and a communication technique in the networking layer (Barrage Relay Networking™) designed to handle mobile networking for multiple hops and scalable to a network of hundreds of radios. The TW-400 CUB TSM radio can transmit voice, position location information and video data.



Figure 1-2 TW-400 CUB TSM Radio

Image courtesy of TrellisWare Technologies Inc.

The TW-400 CUB TSM radio requires an external speaker and microphone; it accommodates earbud headsets, shoulder microphones and other compatible voice accessories. Input ports also accommodate a variety of sensors, including position location systems and video cameras. The device contains built-in GPS, an analog to a digital H.264 encoder for streaming real time video, and cellular-quality voice channels. The TW-400 CUB TSM radio measures 4 x 2.5 x 0.9 inches and weighs 10 ounces. It has an operating temperature range of -20⁰ Celcius (C) to 50⁰ C, is immersible to 2 meters and meets the environmental standard MIL-STD-810G.

2.0 EXPERIMENTATION DESIGN

A detailed description of the experimentation design can be found in the *Experimentation Plan for TrellisWare's TSM Tactical Radios for Communications and Tracking in Urban and Subterranean Environments* (Murtagh, 2016). The scenario was developed with input from responders and technology developers to simulate a communication scenario in a subterranean subway station.

Six first responder evaluators from local and national agencies were equipped with TW-400 CUB TSM radios. The experimentation scenario focused on the use of the radios to facilitate communication to and from a street-level, fixed command center outside of a subway station with mobile units within the subterranean levels of the subway station. Voice and video were transmitted over multiple radio hops. The experiment collected information on the reliability and availability of communications, the number of radio nodes needed to provide environment coverage, the range and the applicability to different mission scenarios. After the field experiment, evaluators were asked to consider how this technology would affect their current standard operating procedures and whether this technology could be used to augment them in a positive way.

2.1 EVENT DESIGN

The experimentation took place at the MTA NYCT's West 4th Street subway station, located at the corner of Waverly Place and Sixth Avenue in New York City. This subway station consists of four underground levels: the turnstile level down one flight of stairs from the street and three lower levels of passenger platforms (Figure 2-1).

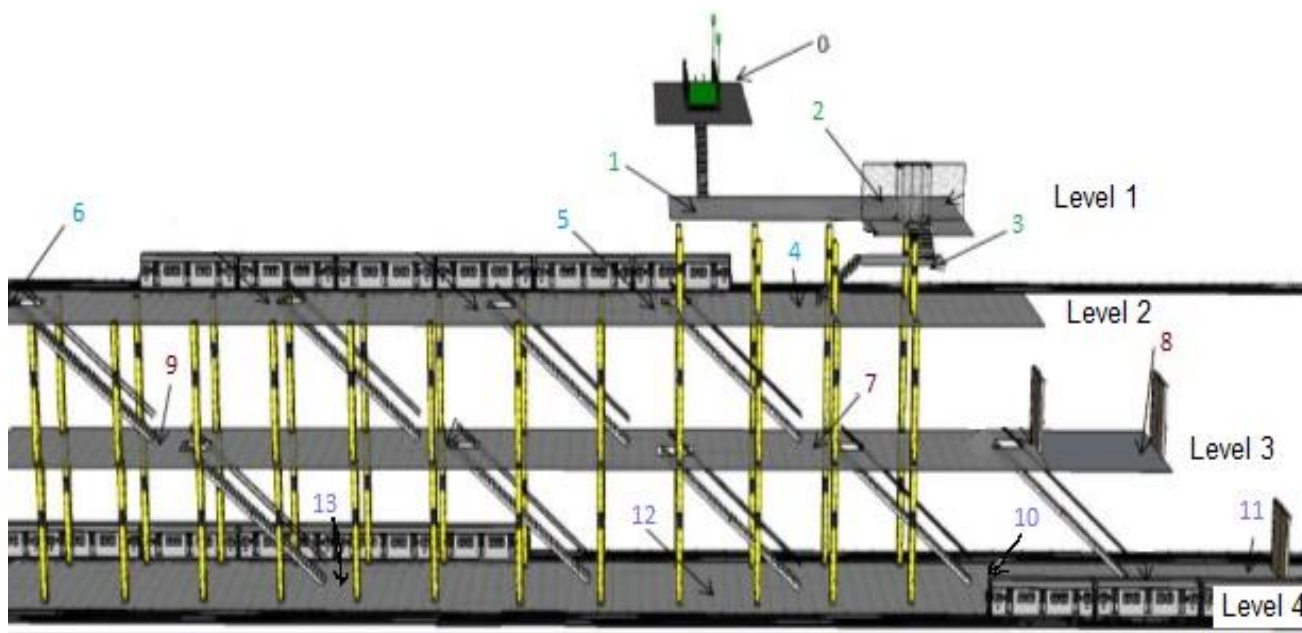


Figure 2-1 West 4th Street Subway Station

NUSTL used prior NIST research that mapped path loss in the multi-level subway station, as seen in this image modified for Urban OpEx. A “command node” was placed outside of the station at street-level (point 0) and radio checks were conducted at each numbered point during the experiment.

Image courtesy of NIST Technical Note 1792

The subterranean station spans approximately three city blocks in length and is representative of a GPS-denied and difficult urban communications environment. This station was selected because it was used in other communications research led by the National Institute of Standards and Technology (NIST), documented in Technical Note 1792 (Young & et. al, 2013).

In their research, NIST used continuous wave transmitters of five different frequencies with receiver equipment to measure and calculate path-loss through a section of the subway station. Path loss, also referred to as path attenuation, defines the reduction in strength experienced by a signal as it penetrates and travels through a structure and is measured in decibels (dB). Path loss can negatively affect the capability of first responders to send a signal to or receive a signal from an incident command post. The NIST study found that with an incident command post located outside of an entrance to this subway station (see point 0 in Figure 2-1), the maximum measured path loss was 240 dB, with the greatest attenuation at the deepest level, farthest from the command post. The study also showed the greatest change occurs between the street level command post and Level 1. Each level deeper increases the path loss from the street level, but not to the same degree as the initial level change. Table 2-1 summarizes the median path loss values found for the subway station levels at five different transmission frequencies. Detailed descriptions of the path loss measurements, calculations and uncertainties can be found in NIST Technical Note 1792 (Young & et. al, 2013).

Table 2-1 Median Path Loss Estimates in Decibels for West 4th Street Station

Subway Platform Level	Median Path Loss (dB) at Different Frequencies				
	430 MHz	745 MHz	905 MHz	1834 MHz	2405 MHz
Level 1 Turnstile level	100.8	106.7	110.1	125.1	117.8
Level 2 First passenger platform	138.3	142.0	147.9	166.7	160.1
Level 3 Middle passenger platform (no tracks)	173.4	185.3	195.7	191.9	200.4
Level 4 Deepest passenger platform	167.3	188.6	191.7	198.0	205.4
dB = Decibel: A unit used to measure the intensity of a sound or the power level of an electrical signal by comparing it with a given level on a logarithmic scale.					
MHz = Megahertz: A unit of alternating current or electromagnetic wave frequency equal to one million hertz (1,000,000 Hz).					
Data included in this table is from cited NIST Technical Note 1792 that shows how the path-loss increases with distance from street level and varies with different transmission frequencies. For comparison, the TW-400 CUB TSM radios used at Urban OpEx operate at 1775-1815 MHz and 2200-2250 MHz frequencies.					

At Urban OpEx, 13 of the locations used in the NIST study were selected as points to conduct radio checks. These points spanned all levels of the station; all were on the southbound train platforms. A simulated incident command post was established outside the entrance to the subway at street level. This consisted of one evaluator equipped with a TW-400 CUB TSM radio, and a technology developer representative with a radio and tablet displaying network information. The five remaining evaluators entered the subway station as a group along with NUSTL data collectors and an additional technology developer representative. The evaluators traversed the test points in numerical order, conducting radio checks back to the command post at each location.

Additionally, at points 4, 7 and 12, the technology developer representative used a GoPro camera, attached by cable to his radio, to stream video over the network back to the command post to be viewed on the command post tablet. As evaluators reached a point where the network connection to the command node was broken (noted by a failed transmission or “exit net” radio declaration), one responder moved back into network range and remained there to act as a repeater node between the street-level command post for the rest of the evaluators that continued deeper into the station. The evaluators continued along the predetermined path until the next break in network connection, where another evaluator remained as a repeater node, while the rest moved on. This continued until all points were covered.

When radio checks had been conducted from each test point, evaluators were given free rein to move about the levels of the subway station and dynamically experiment with the radios by walking around bends or behind structural columns and leaving and re-joining the network (Figure 2-2). NUSTL data collectors accompanied each responder and noted any comments or findings of interest. At a designated time, all participants reconvened at street level and returned to the NUSTL facility. During the field experiment, observers remained in a NUSTL conference room and followed along with the experiment’s progress on a visual graphic updated with information relayed back from the street-level incident command post.



Figure 2-2 Levels 2, 3 and 4 of the West 4th Street Subway Station

2.2 SUMMARY OF THE OPERATIONAL EXPERIMENTATION

At Urban OpEx, evaluators from the MTA, NYPD, Boston Emergency Medical Services (EMS) and the Rochester NY Emergency Communications Department convened at the NUSTL facility located in Manhattan, New York, to participate in the TSM Tactical Radios for Urban and Subterranean Environments OpEx.

Representatives from the FDNY, U.S. Customs and Border Protection (CBP), MTA, NYPD and Port Authority Police Department also participated as observers throughout the experiment. A kick-off meeting was held in NUSTL's conference room prior to the field activities that were performed in a nearby subway station. During the meeting, NUSTL personnel provided an overview of the Urban OpEx Program goals and objectives, and NUSTL's experimentation director gave an overview of the operational experiment for the participants and observers. Technology developers from TrellisWare Technologies Inc. gave a presentation on the TSM tactical radios and their existing and emerging products before outfitting the participating evaluators with radios and earbud headsets.

When the operational experiment began, all participants proceeded to the entrance of the West 4th Street subway station, located at Sixth Avenue and Waverly Place, approximately a half mile from the NUSTL facility (Figure 2-3). A technology developer representative assigned names to each unique radio identifier in the software application (app) in his tablet, and each evaluator did a radio check. One evaluator remained at street level with a technology representative and the NUSTL experiment director.



Figure 2-3 West 4th Street Subway Station Location

Image courtesy of TrellisWare Technologies Inc.

The remaining five evaluators, NUSTL data collectors and another technology developer representative entered the subway station as a group and proceeded to each of the test points (Figure 2-4). Both technology developer representatives (at the command post and in the subway station) carried tablets with an app that showed all of the radios in the network and color-coded dots representing each radio's connection strength to the "command node" at street level.

For the experiment, the need for a repeater node was evidenced by a failed radio check, and/or by the color indication of the connection strength on the tablet software application. All evaluators were connected to the network, but one was designated to communicate back to the command post until the first repeater node was required. At that point, that evaluator remained in place with their TW-400 CUB TSM radio as a repeater node while the rest of the group continued on, with the next designated evaluator responsible for communicating back to the command post.

Early on in the experiment, one evaluator experienced difficulty hearing the communications; this was resolved by adjusting the earbud headset. The group successfully communicated back to the command post from points 1 through 3, but lost network connection moving toward point 4. One evaluator then moved back into the network and remained at point 3 as a repeater node, while the rest of the group moved on (Figure 2-5). During the experiment, radio checks were sometimes repeated because of difficulty hearing due to ambient noise or a poor connection. It was observed that, even at the same location, network connection quality back to the command post could vary. This appeared in some cases to be based on situational environment changes; for example, the presence or absence of people in the narrow entrance staircase from the street.

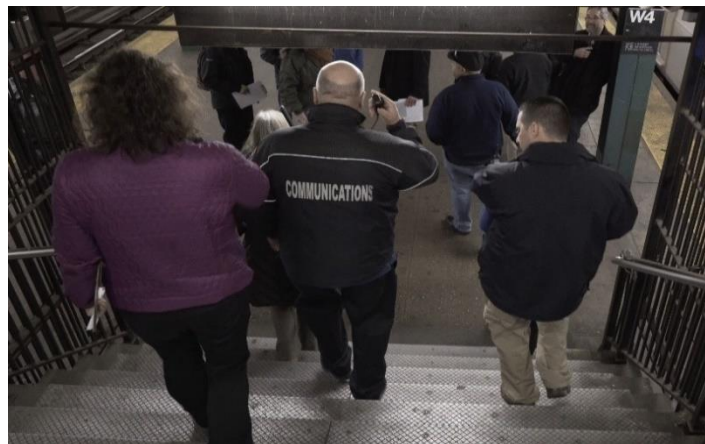


Figure 2-4 OpEx Evaluators and NUSTL Data Collectors in the West 4th Street Subway Station

The group successfully communicated with the command post at points 4 through 6 over a single radio hop (i.e., with one repeater node at point 3). Communication was lost and then momentarily reconnected at point 7; however, the connection was poor, so a second repeater node was established back within coverage at point 5. Communications were successful in points 8 through 13 with occasional difficulty hearing due to background noise. After communications were transmitted from the planned 13 points, the group continued beyond point 13 to try communications from the farthest publically-accessible location at the south end of the deepest subway level; this communication was successful after the evaluator acting as the second repeater moved from point 5 to point 6.

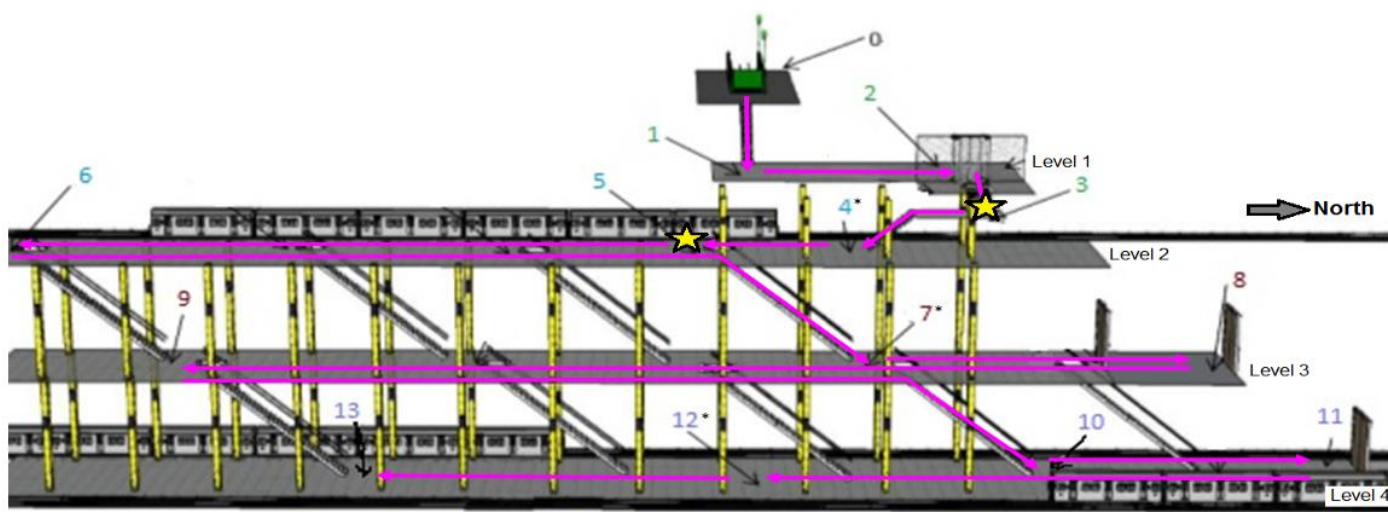


Figure 2-5 West 4th Street Subway Station

Arrows represent the path taken by the evaluators. Stars represent where the repeater nodes were located.
Image courtesy of NIST (Note: Figure is not scaled and has been modified for this experiment)



Figure 2-6 TW-400 CUB TSM Radio on Roof of NUSTL's Facility

Image courtesy of TrellisWare Technologies Inc.

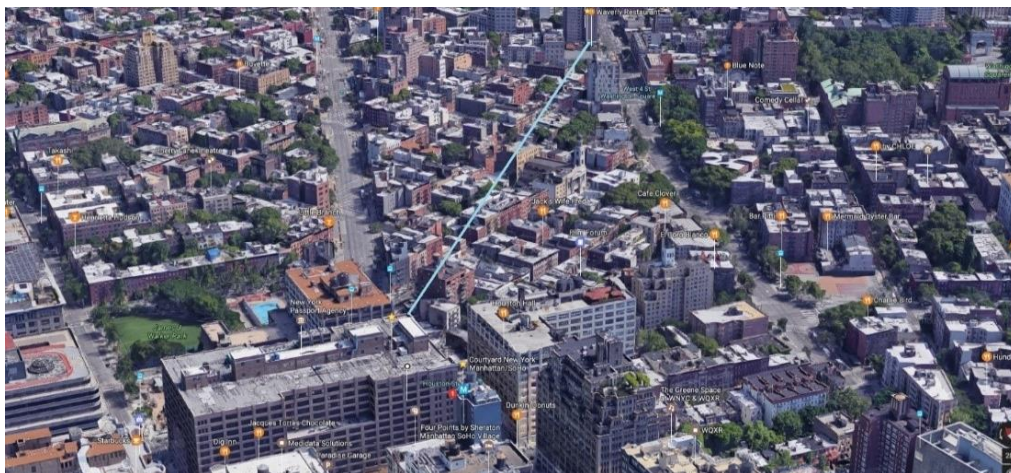
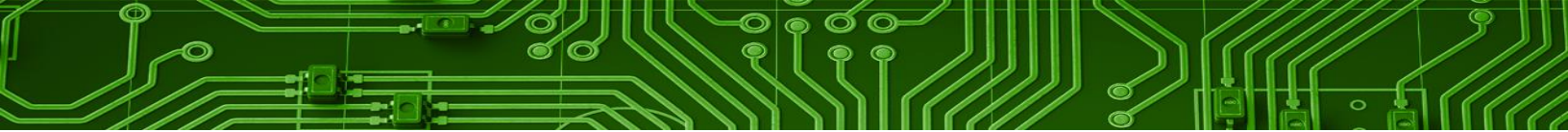


Figure 2-7 Distance Between the NUSTL Facility and West 4th Street Subway Station (2,217.42 ft)

Image courtesy of TrellisWare Technologies Inc.



With these additional radios acting as network links, the observers who remained in the NUSTL conference room were able to both hear communications and see video footage transmitted from the evaluators within the underground subway at a distance of approximately a half mile through an urban environment (Figure 2-7).

In the second part of the experiment at the subway station, the evaluators split up and spent approximately 10 minutes moving freely about the station. Each evaluator was paired with a NUSTL data collector who captured any findings of interest. Three of the evaluators remained on the southbound platforms used for the structured part of the experiment. One reported they maintained clear communication roaming among levels 2, 3 and 4. One evaluator, with permission and an escort, entered a non-public area beyond point 8 on level 3, and reported a good communications connection at approximately 200 feet farther north than the tested point 8 along that level.

One evaluator crossed over to the northbound tracks and found poor reception at the south end of level 3. At level 4 of the northbound tracks in sight of other evaluators on the southbound tracks, the radio check back to the command post was good. This evaluator found that on level 4 of the northbound track parallel to point 12, connection was lost when trains entered the station, and reestablished when trains cleared. Upon signal from the command node, all of the responders reconvened at street level and proceeded back to NUSTL for debriefing and discussion.

Back at the NUSTL conference room, the experimentation director led the evaluators and observers in a discussion to gather feedback on the TW-400 CUB TSM radios. Evaluators who had operated the radios during the experiment also filled out written surveys about the technology. The point of this discussion was to engage the evaluators in a conversation leading to feedback that might not be gained from the survey. Notes were taken and incorporated into the results (Section 3.0) of this report.

3.0 RESULTS

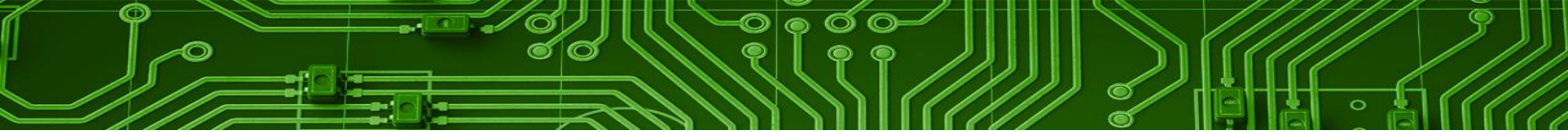
3.1 DATA COLLECTION

During the field portion of the experiment, NUSTL data collectors recorded evaluator comments as they used the TW-400 CUB TSM radios. After experimenting with the radios, the evaluators completed a questionnaire eliciting their opinions of the radios' features and suitability for use by their organizations. Finally, following the experimentation, the evaluators along with observers participated in a debrief session led by the experimentation director. The evaluators liked many aspects of the technology: positive comments were made about the ease of setting up the network, the communication range into the subway station and capabilities available with the software app. The evaluators also had suggestions for improvement and responses varied as to whether the technology was suitable for their mission. Table 3-1 summarizes feedback consolidated from discussion and the narrative portion of the questionnaires.

Table 3-1 Evaluator Feedback by Topic

Topic	Responder Comments
Application	Customs and Border Protection (CBP) observers saw great value in the technology as a force multiplier to augment operations with limited personnel resources, e.g., in onboard ship inspections and port operations: • For container ship inspections, radio communications are often difficult in the levels below deck. Because of this, operators sometimes need to walk up to the top deck to make calls or personnel must go throughout the ship to recall inspectors before the ship departs. CBP observers were interested in testing this technology with deployable, unmanned nodes throughout a container ship to provide communication coverage on all levels. • CBP observers also saw a potential application in port operations for improving video coverage to counter smuggling and theft of goods. They discussed using the radios, outfitted with external power for 12-hour battery life, along with cameras to transmit security video. They envisioned an unmanned camera network that could be deployed and frequently repositioned to discourage those who may learn to block or avoid fixed camera locations.
	Some law enforcement evaluators stated they believed the technology was unsuitable for emergency response. They noted: • The radio only allows one person to speak at a time. These responders prefer a system that allows other users to break in over the speaker and for all users to be able to hear more than one voice at a time. Responders did not think waiting for others to finish talking over the radio would work in an emergency situation. The technology developer stated that this design was intentional based on requirements of their other customers. • Some responders felt the variability of signal strength based on station conditions was problematic; in an emergency situation, they could not wait for trains to clear the station before communicating.
	Other potential technology applications mentioned were: • Communication aboard cruise ships. The technology developer noted that their product had been successful in providing good coverage with 3 nodes on large cruise ships. • Scenarios with even coverage of fixed nodes for reliability, for example, in later-phase emergency response or clean-up operations, where a network of nodes could be established with no mapping or infrastructure prior to operations and removed after the mission.

Topic	Responder Comments
Most Useful Features	When asked what were the most useful features of the technology, evaluators stated: • Clear transmissions; clarity of voice; only minor interruptions of communication. • Ability to monitor team members' status using the app; for example, the command post can monitor the status of radio units in the field (battery life, channel, etc.). • Ease of use. • Ability to send video feed. • Ability to supplement existing P25 radio architecture.
Least Useful Features	When asked what were the least useful features of the technology, evaluators stated: • Inability to hear more than one voice at a time. • Lack of belt clip. • Size (prefer smaller devices, e.g., for concealability). • The need for an attached microphone (no integrated microphone). • Difficulty determining if you are out of the network; also, difficulty knowing if you are disconnected from the command post while still networked with another field radio. • Having to carry a second device to supplement existing P25 architecture.
Software App	• Evaluators were positive about the features of the Android app used for the radio network. The app, used at the command post for the OpEx, is viewable on a phone or tablet paired with the radio over Wi-Fi. Evaluators noted: • It would be a help for agencies with limited resources and personnel. • It is useful that the software can be used to turn off a hot mic (i.e., inadvertent transmissions from a user). • It is useful that the software can be used to correct an operator's incorrectly selected radio channel. • Evaluators would also find it useful to have the information (e.g., signal status) in the app; however, this entails pairing the radio to a smartphone. • Evaluators mentioned that an audio alert would be more useful than the existing visual alert that signals a specific user losing network connection.
Video	Evaluators were positive about the capability to stream video using the radios. They noted: • If the technology were able to get 30 frames per second (instead of the current capability of 15 frames per second), then the video could be useful for evidentiary purposes. The technology developer stated this would be available soon. • Increased frame rate in newer models could allow for integration with fire alert camera systems.
Recommendations	When asked how this technology could be improved, evaluators suggested: • Increase battery life to greater than 12 hours, corresponding to a work shift. • Make the radio smaller. • Create a unit suitable for unmanned deployment in areas where a node or additional radio coverage is needed. • Adapt technology for interoperability with NYC first responders. • Make the supplemental performance capabilities more explicit. • Integrate with additional sensors such as: carbon monoxide monitoring systems; chemical, biological, radiological, nuclear or explosive sensors; or facial recognition cameras and software.



Topic	Responder Comments
Experiment	Participants also provided comments related to the Urban OpEx experiment: • An evaluator would have preferred to use the subway station’s standard track naming convention (as opposed to experiment plan numbers) during the experiment for more realism. • Some evaluators would have preferred more training in the use of the radios before the experiment as they were unfamiliar with earbud use and the radio’s “exit net” declaration when leaving the network. • An evaluator mentioned that earbuds were not suitable for emergency responders as they hampered situational awareness. The radios do accommodate other interfaces, such as shoulder microphones, that were not used during this experiment. • One participant mentioned the experiment was carried out in the radio’s government-exclusive frequency band, not the frequency bands to which first responder’s typically have access. TrellisWare Technologies Inc. is developing a radio that will work in law enforcement bands that should be available by the end of 2017.

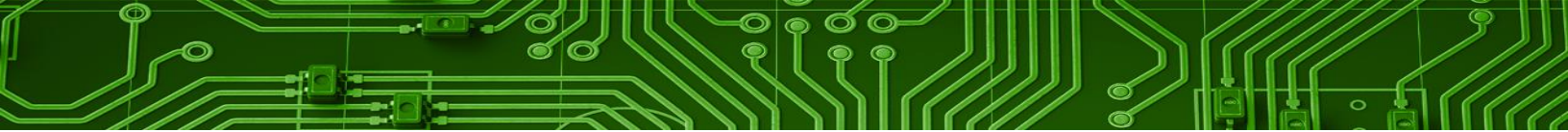
When asked what the affect would be if the technology was implemented at each evaluator’s agency, the majority of evaluators stated that it would require them to augment their concepts of operation. They mentioned positive aspects of having additional capabilities (e.g., live video streaming, GPS, interoperability with other technologies) and challenges of new technology acceptance, additional equipment and required training.

3.2 QUESTIONNAIRE FEEDBACK

Additionally, evaluators completed a questionnaire related to how the technology may fit in with their agency or daily operations. Table 3-2 summarizes these results.

Table 3-2 A Breakdown of the Evaluators’ Responses to NUSTL’s Debrief Questionnaire

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unable to Determine
This technology can help me fulfill my mission	2	0	0	2	2	0
This technology is an improvement on the technology I currently use	1	0	1	1	2	1
The user interface was intuitive and easy to engage with and understand	2	0	0	3	1	0
This technology increases my ability to communicate and disseminate information during an event or incident	2	0	0	1	3	0
This technology increases my ability to control the flow of information to the right groups and people	2	0	0	1	3	0
This technology can improve my ability to communicate and coordinate with other agencies and groups	0	0	1	1	2	2
This technology can improve my ability to review and report information back to my leadership	2	0	0	1	3	0
The numbers within each column represent the number of evaluators who selected that rating in response to the corresponding question.						



3.3 CONCLUSION

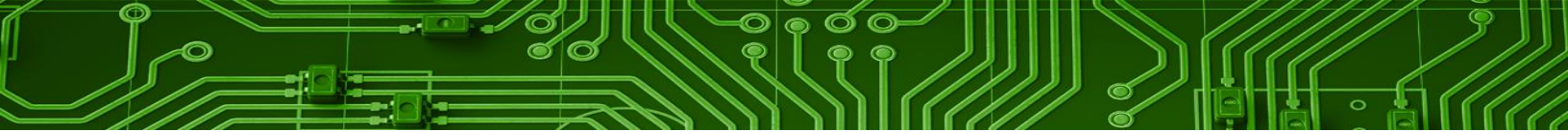
This Urban OpEx introduced the TW-400 CUB TSM radios to emergency responders who had no prior experience with the technology. It explored the use of the radios in a multi-level underground subway station and examined communication coverage, range, reliability of communications and additional features. It allowed the technology developer to hear the priorities and perspective of a variety of first responder participants.

This Urban OpEx was designed to simulate a response situation where an incident commander needs to communicate with field personnel deploying into a difficult RF urban environment. The underground, multi-level subway station used for this experiment was previously characterized for radio signal attenuation, with median path losses from 100 dB between the street and first level to over 200 dB between the street and the deepest platform levels. The TrellisWare Technologies Inc. TW-400 CUB TSM radios can transmit voice, video and sensor information within and out of a difficult RF environment by forming a mesh network where communication coverage can be extended with additional radio nodes. The subway response scenario used in Urban OpEx is not claimed to be the best or only application for this technology.

During the experiment, communications were successful throughout the subway station with the use of two radio node links to the command post. The distance for the first communication hop (i.e., from the street level command center to the first repeater node) was smaller than that of other communication hops throughout the rest of the station. This result correlates with results from the NIST study showing that the greatest attenuation is between street level and level 1, likely due to the dense concrete construction and narrow opening at the subway entryway. Outside of the subway station, the TW-400 CUB TSM radios had a range of at least a half mile through the city as evidenced by the successful connection from the subway command post to the NUSTL building. No experiments were carried out to characterize the radios' maximum range in the outdoor city environment.

Within the subway station, network strength varied based on transient conditions. It was observed that radio connection was degraded when the narrow stairway between the street level command post and first radio node filled with people (e.g., after a train arrival). One evaluator also observed a loss of connection from others on a parallel platform when they were separated by a train arrival.

Video was successfully transmitted in all three test points covering the 2nd, 3rd and 4th levels, with some quality issues. In some instances, the image was frozen or pixelated. The technology developer stated that video transmission is improved when a good network connection is ensured before sending. The network would be better with more nodes spread evenly throughout the subway station; however, this was not the scenario with which we were experimenting.



4.0 REFERENCES

- Murtagh, C. (2016). *TrellisWare TSM Tactical Radios for Communications and Tracking in Urban and Subterranean Environments Experimentation Plan*. New York: U.S. Department of Homeland Security's National Urban Security Technology Laboratory.
- Young, W., & et. al. (2013, March). *Performance Analysis of RF-Based Electronic Safety Equipment in a Subway Station and the Empire State Building*. National Institute of Standards and Technology. Retrieved from <http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1792.pdf>