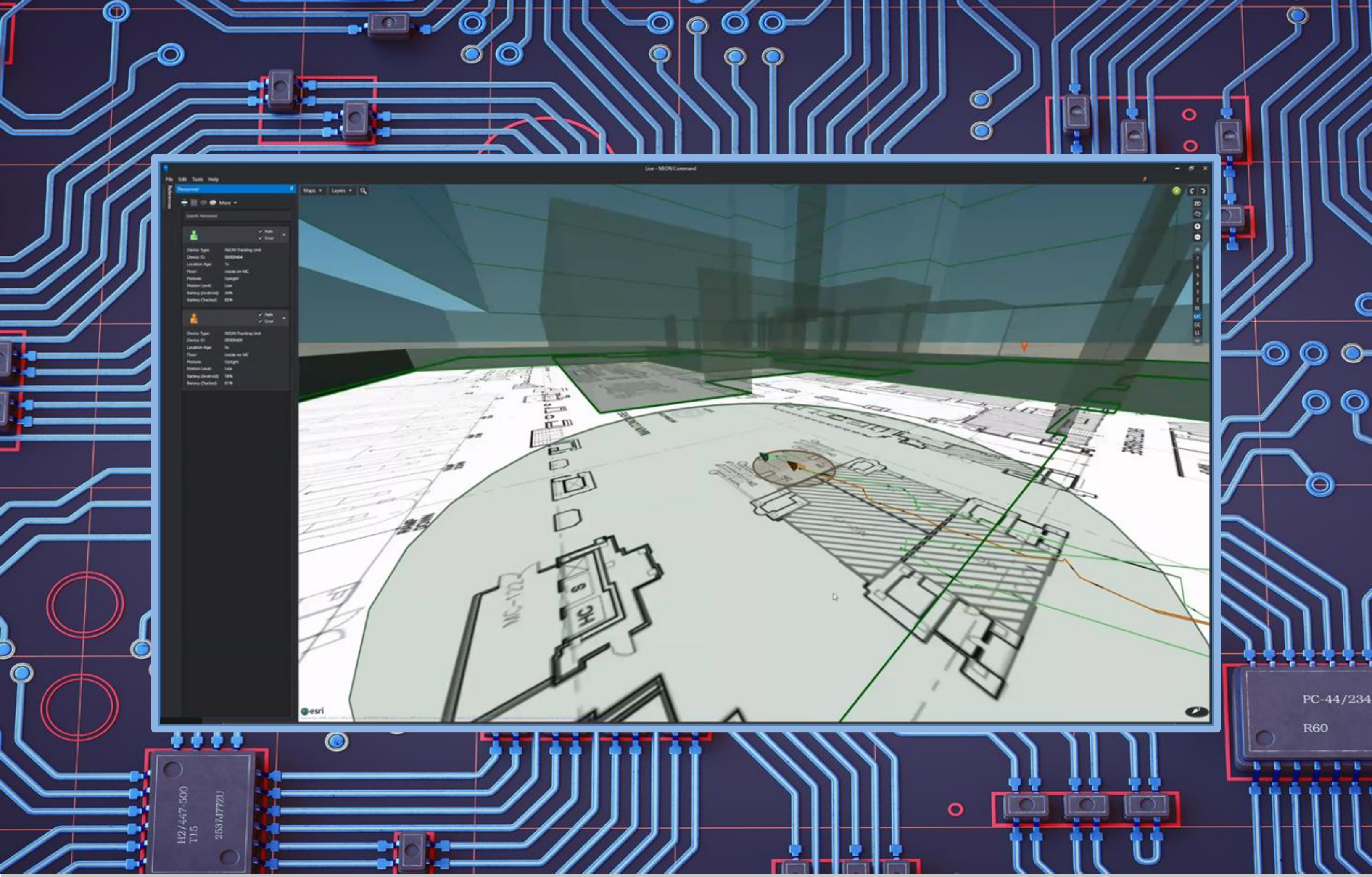

TRX NEON Personnel Location Tracker

Technology Demonstration Report

February 2022

Homeland Security
Science and Technology

NUSTL
NATIONAL URBAN SECURITY TECHNOLOGY LABORATORY

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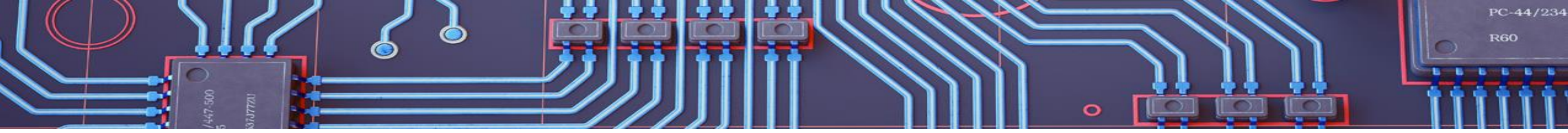

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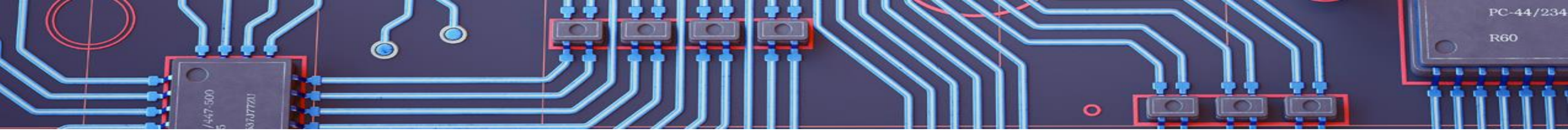


FOREWORD

The National Urban Security Technology Laboratory (NUSTL) is a federal laboratory organized within the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) Office of Innovation and Collaboration, Office of National Laboratories.

Located in New York City, NUSTL is the only national laboratory focused exclusively on supporting the capabilities of state and local first responders to address the homeland security mission. The laboratory provides first responders with the necessary services, products and tools to prevent, protect against, mitigate, respond to, and recover from homeland security threats and events.

NUSTL provides independent technology evaluations and assessments for first responders, thereby enabling informed acquisition and deployment decisions and helping to ensure that responders have the best technology available to use in homeland security missions.

Visit the NUSTL website at www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory or contact NUSTL@hq.dhs.gov for more information.

POINT OF CONTACT

National Urban Security Technology Laboratory
U.S. Department of Homeland Security
Science and Technology Directorate
Office of Innovation and Collaboration
Office of National Laboratories
201 Varick Street
New York, NY 10014

Email: NUSTL@hq.dhs.gov
Website: www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory

Authors:
Hasan Shahid, Project Lead, NUSTL Test Engineer
Joseph Jankovic, NUSTL Test Engineer
Matthew Monetti, NUSTL Test Scientist

EXECUTIVE SUMMARY

On March 26, 2021, the U.S. Department of Homeland Security (DHS) National Urban Security Technology Laboratory (NUSTL), in collaboration with Metro-North Commuter Railroad Company (MNR), conducted a semi-virtual technology demonstration of the TRX NEON® Personnel Location Tracker. MNR conducted the demonstration on site at Grand Central Terminal (GCT) in New York City, NY while representatives from NUSTL and TRX Systems, and other observers attended virtually via a video conference bridge.

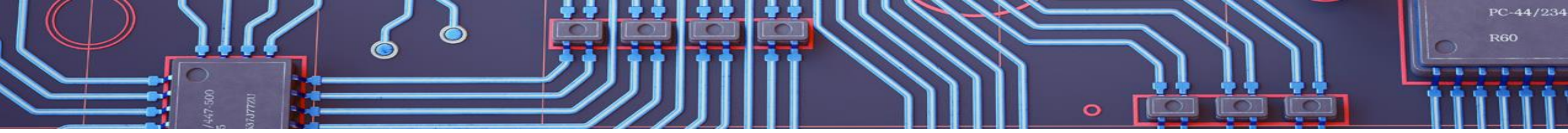
MNR used the TRX NEON technology to conduct an emergency preparedness environmental survey of GCT. By time-synchronizing the TRX NEON with environmental sensors, MNR will be able to attribute environmental measurements to specific locations in GCT and generate maps that can be used in situational awareness platforms such as the Environmental Systems Research Institute (ESRI) ArcGIS or the Federal Emergency Management Agency's (FEMA) CBRNResponder.

The technology demonstration, which was separate from the survey, consisted of a presentation by TRX Systems on the TRX NEON technology, five location tracking use cases, and a debrief session. Location tracking use cases included the following:

- Single user, GPS-enabled tracking;
- Multiple user, GPS-enabled tracking;
- Multiple user, GPS-denied tracking;
- Multiple user, three-dimensional tracking; and
- Single user, beacon-assisted tracking.

MNR found that the location data accuracy provided by the TRX NEON technology was sufficient for scientific usage, such as a survey of GCT, if a proper initialization was performed and either regular manual corrections were performed, or reference beacons were deployed. MNR and NUSTL noted that reference beacons, rather than manual corrections, may be more appropriate for emergency response operations as the frequency of manual corrections necessary to produce accurate data may distract from the task at hand.

After the demonstration, NUSTL determined that the TRX NEON technology fully met 14 out of 20 requirements for location trackers, partially met one requirement and did not meet two requirements. Insufficient data was collected to make a determination about three requirements. While available data proved that the TRX NEON technology met parts of the definitions of these requirements, it could not demonstrate that the device fully met the requirements. An additional five requirements were developed but not evaluated during the technology demonstration. These requirements included the placement of reference pins, manual corrections while post-processing data, and data integration with other sensors and situational awareness displays.



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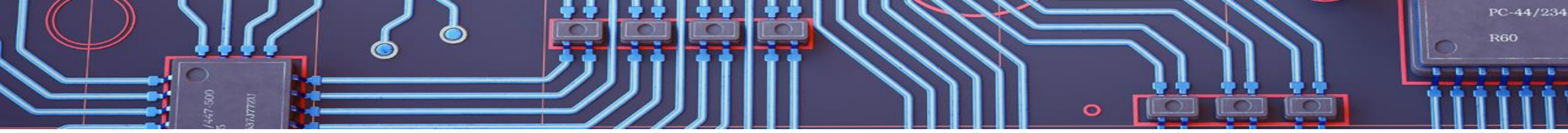


1.0 INTRODUCTION

The MNR Security Department conducted an emergency preparedness environmental survey of GCT in 2021. MNR expressed an interest in using a location tracker to support this survey during a meeting between MNR and NUSTL in 2019. The TRX NEON Personnel Tracker can provide location data that could complement data provided by mobile environmental sensors, enabling the accurate mapping of survey results to specific locations throughout GCT. NUSTL, in conjunction with MNR, facilitated a demonstration of the technology on March 26, 2021 to determine its feasibility in supporting an emergency preparedness environmental survey.

The TRX NEON technology is deployed with a Location Service App running on an Android device combined with a small, body worn accessory (NEON Tracking Unit) on each tracked person. The NEON Location Service takes inertial and ranging sensor data from the Tracking Unit and fuses it with GPS, terrain data, and available map and building data to calculate the user's location. Each layer of technology provides constraints to help improve the location accuracy. Location data is transmitted to a server via a smartphone, using WIFI or LTE. Data can then be viewed in situational awareness display platforms such as ESRI ArcGIS or FEMA's CBRNResponder.

Due to health and safety risks posed by the COVID-19 pandemic, NUSTL participated in the demonstration virtually via a video conference platform. NUSTL loaned the TRX NEON equipment to MNR, remotely guided MNR through demonstration activities designed to showcase the TRX NEON's capabilities, and remotely conducted data collection procedures during the demonstration.

Following the demonstration, MNR conducted an indoor survey within the remainder of the equipment loan period. It is anticipated that data collected during the survey will be used to create emergency preparedness maps of GCT.

1.1 Venue Overview

GCT is a major public transportation and commuter hub located in New York City. GCT hosts 44 train platforms and serves MNR. GCT is connected to the New York City Transit Authority's subway station, Grand Central Station and the East Side Access (ESA) project, expected to be completed in 2022, will connect Long Island Rail Road (LIRR) service to GCT. GCT also hosts several restaurants and retailers and is a major tourist attraction in New York City, with approximately 750,000 visitors every day[i] .

The TRX NEON demonstration was conducted in various areas of GCT, including the Main Concourse, the Dining Concourse, train platforms, maintenance hallways and MNR offices. Prior to the demonstration, NUSTL worked with MNR to select Global Positioning System (GPS)-enabled and GPS-denied locations in GCT to demonstrate the capabilities of the TRX NEON technology.

Figure 1-1 Grand Central Terminal Main Concourse
Image courtesy of: http://www.grandcentralterminal.com/about/.

[i] "About Grand Central Terminal." Grand Central Terminal. 2021. <http://www.grandcentralterminal.com/about/>.

1.2 TRX NEON OVERVIEW

The NEON Personnel Tracker Application, developed by TRX Systems, is a geolocation sensor that provides personnel location data. In particular, the device can provide location data in indoor, underground and in other GPS-denied environments. The systems use an inertial sensor which is mounted on a belt clip and worn on the body near the waist. The NEON Application derives location data from inertial sensor data, Bluetooth and Wi-Fi signal strength readings, and inferred map and building data. TRX NEON tracking units can also use third party stationary Ultra-wideband (UWB) or Bluetooth low energy (BLE) beacons deployed throughout a facility to enhance the accuracy of the location data. If third-party beacons are not available, then the NEON trackers themselves can be deployed as beacons.

Location data from the TRX NEON Location Service can be viewed in a variety of software applications all developed by TRX Systems, such as the TRX Personnel Tracker, Signal Mapper Applications optimized for mobile platforms, and the TRX Command 3D software, which allows for three-dimensional location tracking. These software applications can also import building plans to create digital three-dimensional building models. Location data can be exported as a file or via API to be viewed in other situational awareness display software applications, such as ESRI's ArcGIS and FEMA's CBRNResponder.

NUSTL provided MNR with four trackers and access to TRX software for the demonstration. NUSTL also provided three Samsung Galaxy S7 smartphones and one Samsung Galaxy S9 smartphone to serve as the sensor platform for the TRX NEON trackers and three portable power packs to serve as external backup power sources for either the smartphones or location trackers. The smartphones loaned to MNR were not equipped with SIM cards and were therefore only able to access Wi-Fi networks at GCT, but not cellular networks.

Figure 1-2 TRX NEON mounted on a tactical vest
Image courtesy of TRX Systems

Figure 1-3 Three-dimensional building model in TRX Command
Courtesy of TRX Systems

1.3 LOCATION TRACKER REQUIREMENTS

Prior to planning the demonstration, NUSTL compiled a list of requirements for location tracking technology, including desired performance specifications and features using notes taken during the meeting with MNR referenced in Section 1.0. These requirements, which were verified by MNR, are listed in this section.

1) Location Tracking Requirements

   1.1) **GPS-Enabled Accuracy**. Location trackers should provide outdoor location tracking with an accuracy of three meters.

   1.2) **GPS-Denied Accuracy**. Location trackers should provide location tracking in GPS-denied areas with an accuracy of ten meters.

   1.3) **Three-Dimensional Accuracy.** Location trackers should provide three-dimensional location tracking with an elevation accuracy of three meters.

   1.4) **Beacons for Improved Accuracy**. Location trackers may use pre-deployed beacons or nodes to improve accuracy of location data.

   1.5) **Reference Pins.** Users can save position information (or “drop a pin”) at any location. The pin is saved and can be used for retroactive reference.

   1.6) **Manual Data Correction**. Location trackers allow the ability to manually correct systematic errors in previously recorded location data.

2) Communications Requirements

   2.1) **Communications with Sensor Platform.** Location trackers and sensor platforms (i.e., smartphones) should be supported by a wireless personal area network (WPAN).

      2.1.1) **WPAN Connection Duration.** WPAN connection between location trackers and sensor platforms will be maintained 95 percent of the time duration of the operation and will experience minimal disruptions.

      2.1.2) **WPAN Disruption Notification.** WPAN will provide notification to the wearer upon disconnection between the location tracker and the sensor platform.

   2.2) **Communications with Server**. Sensor platforms will transmit data to servers over cellular networks or Wi-Fi networks.

   2.3) **Data Caching.** Location data will be cached in the case of a dropped network connection (WPAN or external network) and retransmitted upon re-establishment of connection.

   2.4) **Update Intervals.** Data is updated at two-second intervals by the sensor and on the smartphone. Data is updated at two-minute intervals on desktop-based situational awareness software.

3) Data Integration Requirements

   3.1) **Data Integration.** Location data can be displayed in real time on a situational awareness display alongside data from other sensors.

3.1.1) **FEMA CBRNResponder Integration**. Location data can be displayed in FEMA CBRNResponder.

3.1.2) **ESRI ArcGIS Integration**. Location data can be displayed in a geographic information system (GIS) layer viewed in ESRI ArcGIS.

3.2) **Data Storing**. Location data can be recorded and displayed for later analysis on a situational awareness display alongside data from other sensors.

4) <u>Human Factor Requirements</u>

4.1) **Interference Prevention**. Physical design of tracker does not interfere with the wearer's ability to perform other job-related tasks.

4.2) **Mobility**. Physical design of tracker does not inhibit the wearer's mobility.

4.3) **Deactivation**. Physical design of the tracker does not allow the wearer to deactivate the tracker. This includes both intentional and unintentional deactivation by the wearer. Trackers can only be deactivated by a remote user, such as an incident commander.

5) <u>Miscellaneous Requirements</u>

5.1) **Co-Location with Other Equipment**. Physical design of the location tracker should allow for colocation with other sensors or platforms, if the devices are separate.

5.1.1) **Integration with Other Hardware**. Location tracker hardware is integrated with other sensors or platforms, if possible.

5.2) **Time-Synchronization**. Time-synchronization is possible between multiple location trackers and other sensors or devices.

5.3) **Battery Life**. Location tracker should have a battery life of at least four hours.

5.4) **External Power Source**. Location tracker should have the option to be powered externally.

5.5) **Reconnection**. Location tracker automatically reconnects to sensor platform or other communications server after the initial connection is dropped. A notification is provided to users when reconnection is necessary.

The performance of the TRX NEON system is assessed against these requirements in Section 3.2 of this report.

2.0 METHODOLOGY

2.1 Demonstration Procedures

The technology demonstration on March 26, 2021 opened with a short presentation by vendor representatives from TRX Systems, describing the TRX NEON Personnel Location Tracker, how it works, and how it can be used.

After the vendor presentation, MNR evaluators conducted a technology initialization in the MNR offices at GCT. Two TRX NEON trackers were activated and paired with smartphones. One smartphone was provided by NUSTL and was not long-term evolution (LTE)-enabled. As such, the evaluator with this phone used a Wi-Fi hotspot throughout the demonstration. The other smartphone was an agency phone provided by MNR. This phone was LTE-enabled. The MNR evaluators then proceeded to the starting positions for pre-determined patrol routes. A third MNR evaluator accompanied the TRX NEON wearers. The third evaluator relayed instructions on demonstration procedures from NUSTL to the other two wearers. The MNR evaluators then conducted the five location tracking use cases described in the following sections.

While MNR evaluators were conducting use cases, the TRX Command software was displayed in the video conference meeting by personnel from TRX Systems and NUSTL.

After the five use cases were completed, the MNR evaluators returned to the MNR offices. NUSTL then facilitated a debrief session in which the MNR evaluators were interviewed for feedback on the performance of the TRX NEON system.

2.1.1 Single User, GPS-Enabled Location Tracking

The first location tracking use case demonstrated single-user tracking in a GPS-enabled area. The MNR evaluator performed an initialization of the TRX NEON technology at an entrance to GCT on 42nd Street. The evaluator walked a pre-determined path through the interior Main Concourse of GCT, left the building via an exit on Lexington Avenue, and walked along the exterior of the building to the corner of 44th Street and Lexington Avenue. The evaluator returned to the start of the route via the exterior of the building (south along Lexington Avenue and then west along 42nd Street). Throughout this use case, the MNR evaluator performed manual location corrections on the TRX NEON technology at various locations, including at the corner of 44th Street and Lexington Avenue and the corner of 42nd Street and Lexington Avenue.

Figure 2-1 Single user, GPS-enabled location tracking in TRX Command

While two users are displayed in this image, only the user represented by blue walked the patrol for this use case. The user represented by range remained idle during the use case. The dashed path drawn in red shows the actual patrol route walked by the user.

2.1.2 Multiple Users, GPS-Enabled Location Tracking

The second location tracking use case demonstrated multiple user tracking in a GPS-enabled area. One MNR evaluator performed an initialization at the location described in the previous section, while a second evaluator did not perform an initialization. The first evaluator walked the route described in the previous section, while the second evaluator walked the reverse of the route (along the exterior of the building first and returning to the start via the interior of the building) at the same time.

The first evaluator performed manual corrections throughout this use case at the same locations used in the previous use case. The second evaluator did not perform manual corrections. This was done to demonstrate the error in location data that may occur without manual corrections.

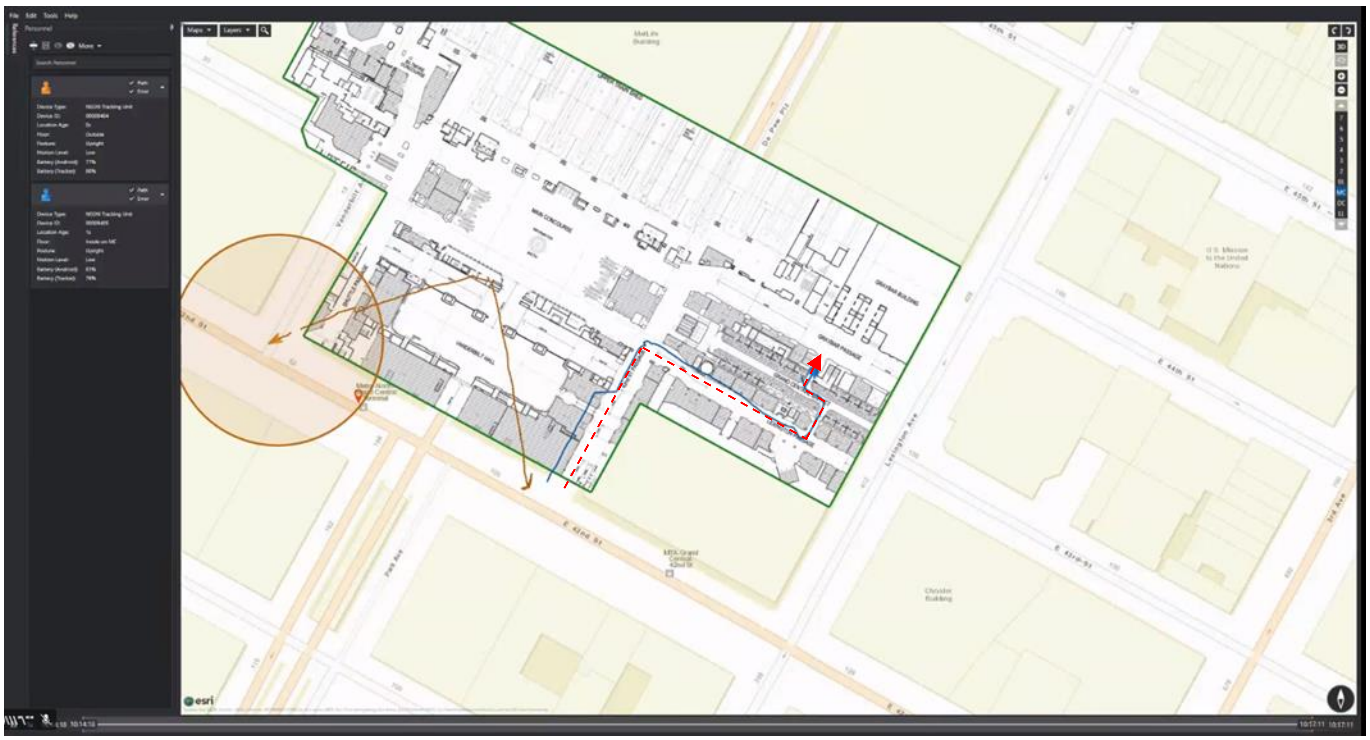


Figure 2-2 Multiple user, GPS-enabled location tracking in TRX Command

The user represented in blue performed an initialization and manual corrections, while the orange user did not perform either. The dashed path in red represents the actual patrol route walked by both users.

2.1.3 Multiple Users, GPS-Denied Location Tracking

The third location tracking use case demonstrated multiple user tracking in a GPS-denied area. Both evaluators performed an initialization at the entrance to the train platform for Track 100 at GCT. Evaluators walked to the end of the platform, turning into maintenance hallways while en route. The evaluators then returned directly to the entrance of the platform.

The evaluators then proceeded to the entrance to the train platform for Track 107 and performed another initialization. The evaluators walked to the end of the platform and then returned directly to the entrance. Unlike Track 100, there were no maintenance hallways along Track 107.

Like the previous use case, the first evaluator regularly performed manual corrections, while the second evaluator did not. This was done to demonstrate the error in location data that may occur without manual corrections.

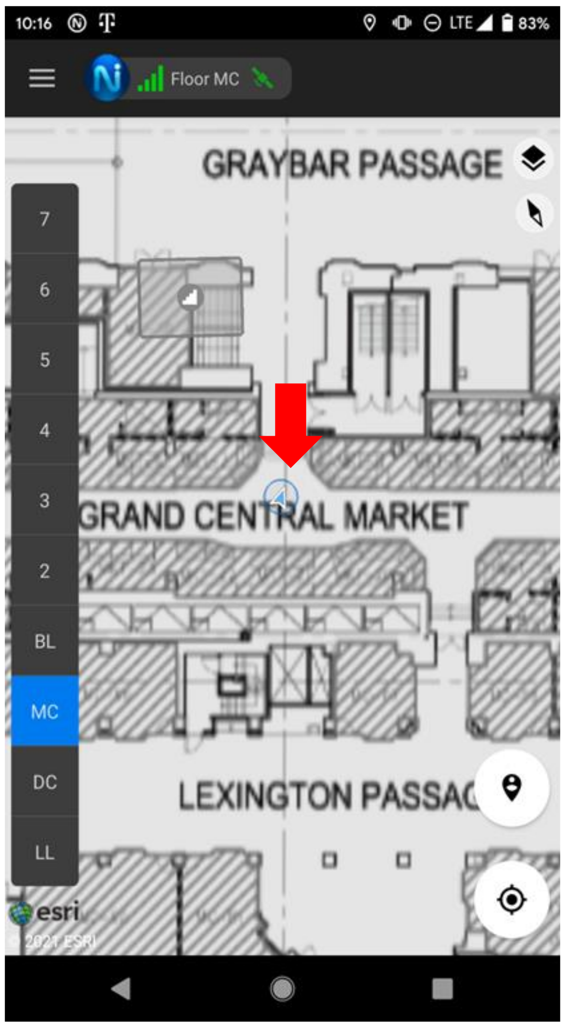


Figure 2-3 GPS-enabled location tracking in TRX mobile app

While this screenshot was taken during the multiple user use case, the second user is not visible as the user did not perform an initialization or manual corrections. The red arrow indicates the location of the user in this screenshot for ease of visibility.

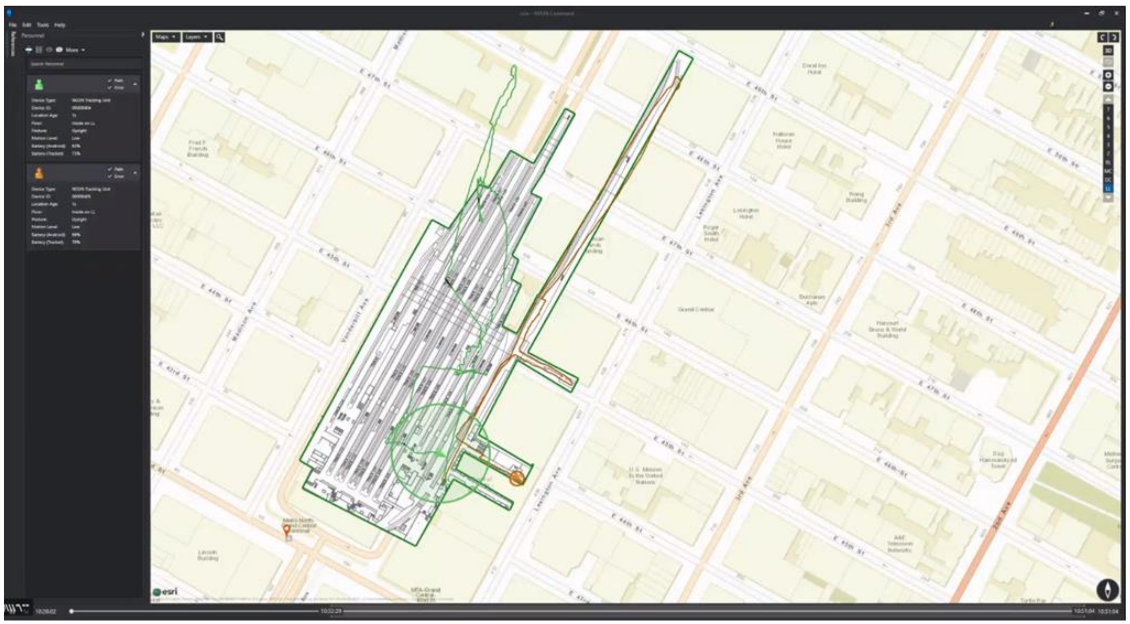


Figure 2-5 Multiple user, GPS-denied location tracking in TRX Command

Both users performed an initialization during this use case. The user represented by orange performed regular manual corrections, while the user represented by green did not.

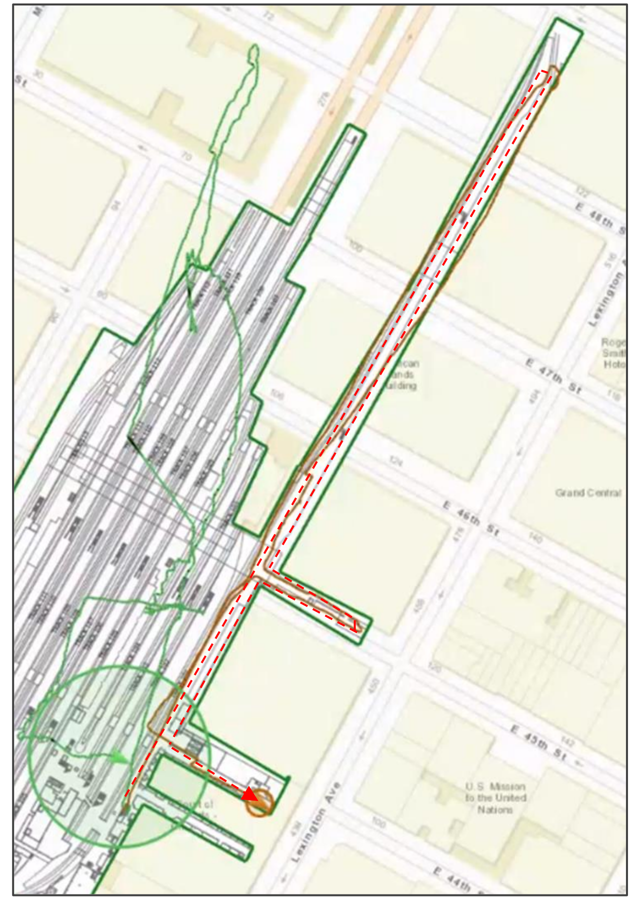


Figure 2-4 Multiple user, GPS-denied location tracking in TRX Command

This figure is a zoomed and cropped version of the previous figure for ease of visibility. The dashed path in red depicts the actual path walked by both users.

Figure 2-6 GPS-denied location tracking in TRX mobile app

While this screenshot was taken during a multiple user use case, the second user is not visible as this user did not perform manual corrections. The red arrow indicates the location of the user in this screenshot for ease of visibility.

2.1.4 Multiple Users, Three-Dimensional Location Tracking

The fourth location tracking use case demonstrated three-dimensional location tracking. Two patrol routes were used for this use case and were walked in sequence. Unlike previous use cases, both evaluators regularly performed manual corrections throughout this use case. One user performed a correction every five minutes, while the other performed a correction every ten minutes.

For the first patrol route, the evaluators performed an initialization on the Balcony Level of GCT. The evaluators then walked a route through the Balcony Level, the Main Concourse, and the Dining Concourse of GCT and returned to the starting position on the Balcony Level. Vertical features included in this route included stairs, escalators and ramps.

After completing the first route, evaluators proceeded to take an elevator to MNR offices on the sixth floor of GCT. The evaluators performed a manual correction after exiting the elevator on the sixth floor and walked the perimeter.

Due to a display error in the video conference meeting platform, evaluators repeated the first patrol route before concluding this use case.

Figure 2-7 Three-dimensional location tracking in MNR offices in TRX Command

The vertical tracks towards the left of the building model indicate the usage of an elevator.

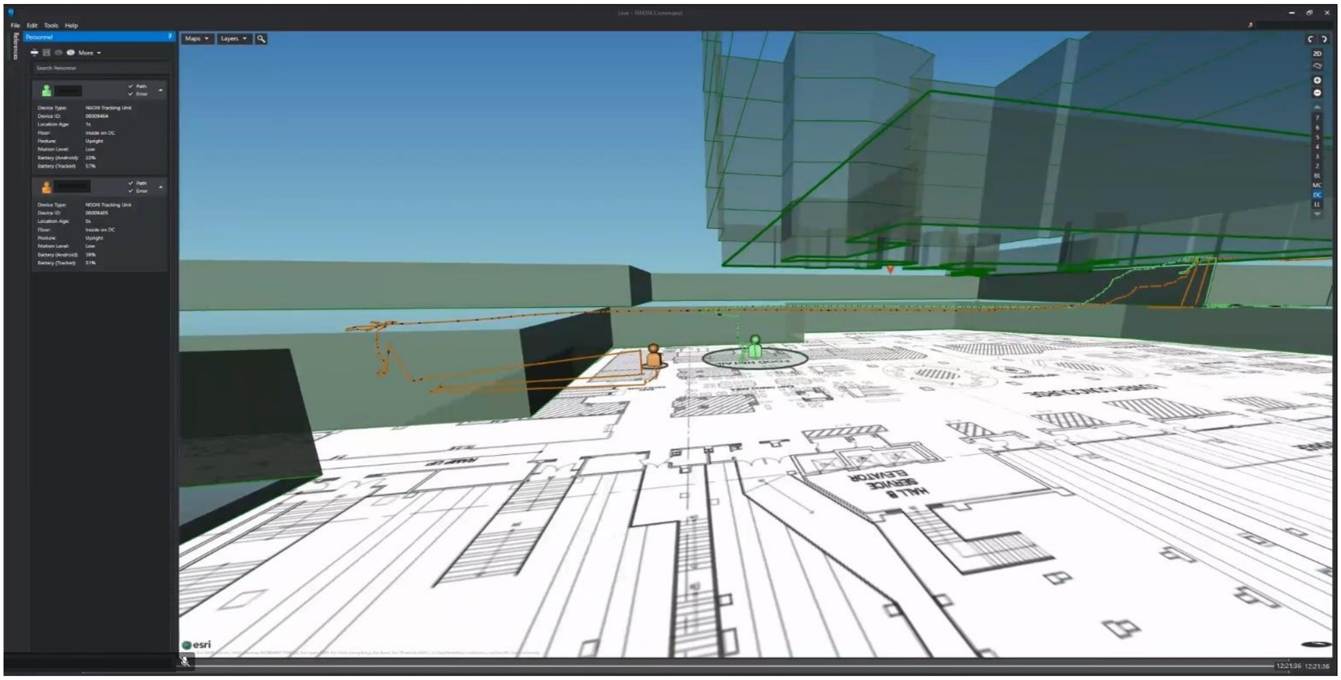


Figure 2-8 Three-dimensional location tracking in Dining Concourse in TRX Command

The vertical tracks towards the right of the screen indicate the TRX NEON wearers walking down a flight of stairs. The vertical tracks towards the left of the screen indicate the usage of an escalator.

2.1.5 Single User, Beacon-Assisted Location Tracking

The fifth and final location tracking use case demonstrated the use of reference beacons to improve location data accuracy. Prior to the start of the use case, three TRX NEON Tracking Units (TUs) were deployed as reference beacons along the train platform for Track 100. The NEON TUs were placed on vertical columns at a height of about five feet.

One MNR evaluator performed an initialization at the entrance to the platform and then walked to the end of the platform, turning into maintenance hallways while en route. The evaluator then returned directly to the entrance of the platform. The evaluator performed manual corrections during this patrol route. However, corrections were performed at a lower frequency than in the use case described in Section 2.1.3.

The evaluator repeated the patrol route before concluding the use case. During the second walk of this patrol route, manual corrections were not performed. This was done to show the differences in location data accuracy when relying solely on reference beacons and when both beacons and manual corrections are used.

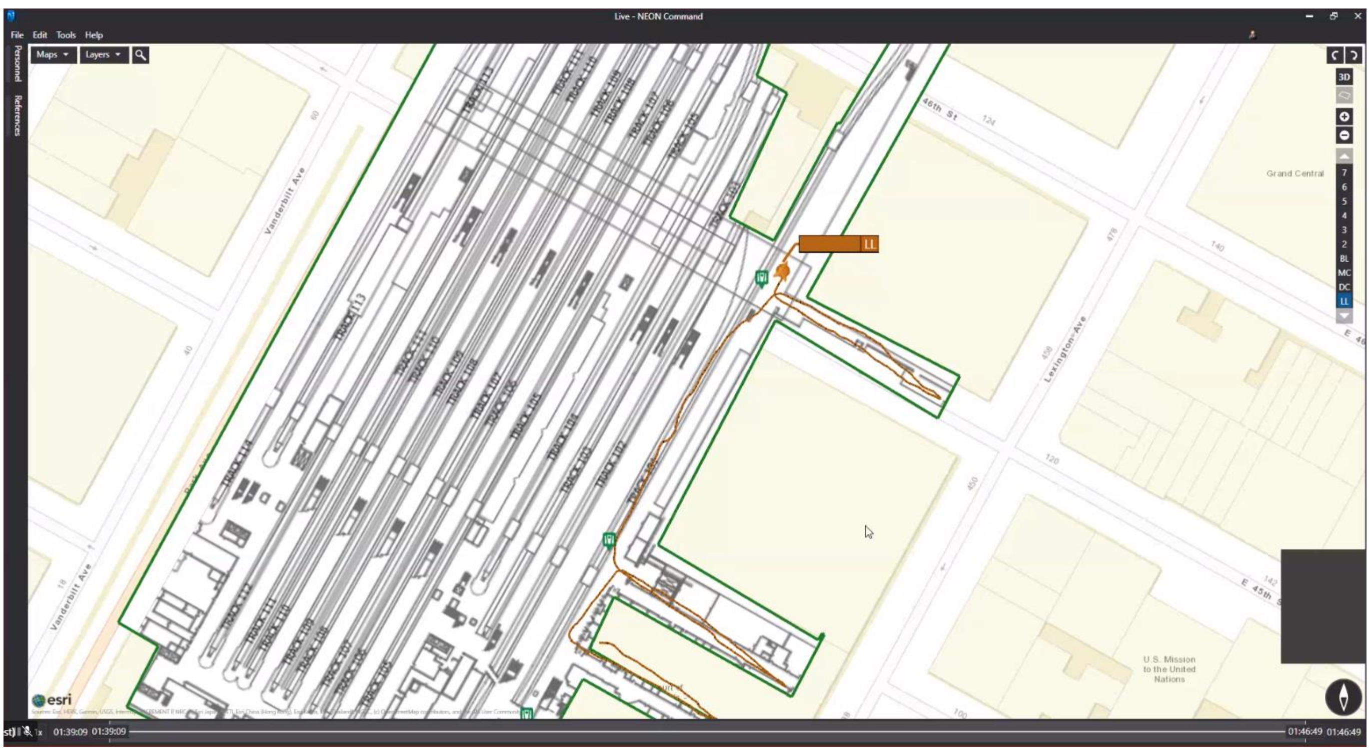


Figure 2-9 Single user, beacon-assisted location tracking in TRX Command

The green icons along the platform represent TRX NEONs deployed as beacons.
See Figure 2-4 for the actual path walked by the evaluator.

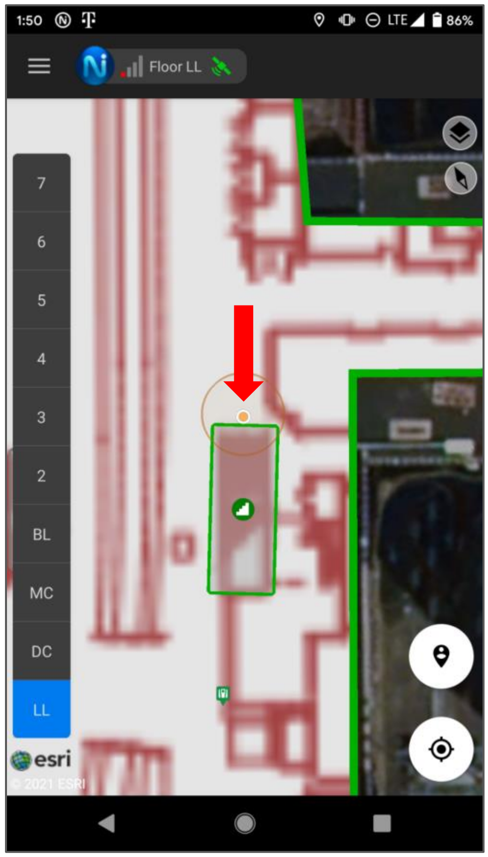


Figure 2-10 Single user, beacon-assisted location tracking in TRX mobile app

The green icon (circled in red for ease of visibility) toward the bottom of the image indicates a TRX NEON deployed as a beacon. The red arrow indicates the location of the user in the screenshot for ease of visibility.

2.2 Deviations From Demonstration Plan

Prior to the demonstration, the NUSTL team developed a demonstration plan with guidance from MNR. The purpose of this demonstration plan was to detail activities that could be used to demonstrate the capabilities of the TRX NEON technology. While the demonstration mostly followed the demonstration plan, there were some deviations from the plan which are detailed in this section.

NUSTL was unable to provide eight third-party Kontakt.io Smart Beacons that were planned for the demonstration due to restrictions imposed by the COVID-19 pandemic. Instead, three TRX NEON TUs were deployed as reference beacons along the train platform for Track 100 to fulfill the requirements for evaluating the fifth use-case of beacon-assisted location tracking. The NEON TUs were placed on vertical columns at a height of about five feet.

MNR evaluators were on-site operating the TRX NEON tracking units and did not perform TRX Command Testing during the demonstration. TRX Command software was operated by personnel from TRX Systems and shared in real-time via the video conference meeting during the demonstration. MNR had access to the TRX Command software prior to the demonstration and used it to prepare for the demonstration by uploading and creating floor plans and 3D models of GCT.

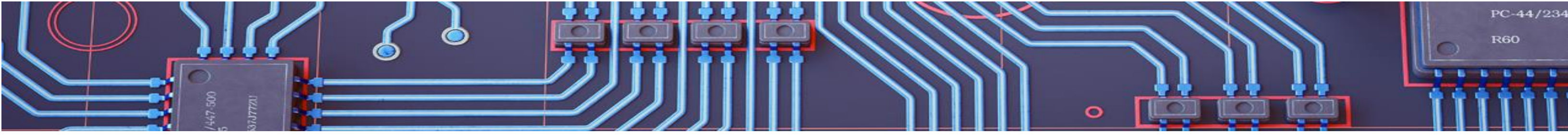
2.3 Data Collection

NUSTL fulfilled the data collection role throughout the demonstration. Data collection was accomplished remotely through a video conference bridge. The content displayed included presentations for briefings and a real-time shared display of TRX Command during the use cases. Two NUSTL data collectors were in audio communication with MNR staff to record notes on technology performance observations, technology malfunctions, and candid comments by MNR evaluators. During the use cases there was a single MNR representative speaking who was alongside the evaluators wearing the TRX NEON devices. During the TRX presentation and debriefing session all MNR evaluators were able to speak. Observers were also able to participate through the video conference connection and their questions and perspectives were sought at times throughout the demonstration.

Written data collection prompts in Appendix A: Data Collection Prompts, were utilized to help ensure all necessary data was acquired during the demonstration. NUSTL and MNR kept a record of which evaluators were equipped with which devices. Serial numbers for each TRX NEON TU and Android phone were recorded for each evaluator. Each evaluator was assigned a distinct color and name, which was displayed in the TRX Command application. Evaluators were asked to take screenshots of the TRX Location Services mobile application on their Android phones every ten minutes or at predetermined locations to take photographs of locations in GCT (public areas only) during the use cases. Data collectors recorded times along with all relevant observations. NUSTL data collectors also captured screen shots every five minutes or less. The debrief session was conducted by asking questions in Appendix B: Debrief Questions. All sources of data were compiled and made available for this report.

2.4 Limitations

The COVID-19 pandemic impacted the design and execution of the demonstration. All non-MNR participants, including NUSTL data collectors, participated remotely through a video conference session because of restrictions imposed on in-person attendance. This limited the ability of data collectors to observe the full surroundings and all events, so some relevant information could have been missed. NUSTL relied on MNR participants to manage the on-site aspects of the demonstration and help relay information through the video conference session.



3.0 RESULTS

3.1 Observations and Evaluator Feedback

This section details observations on technology performance and usability made by the NUSTL team, as well as feedback provided by MNR throughout the demonstration and during the debrief session.

Technology Setup and Installation

- Installation and setup were easy. The most time-consuming piece was creating building maps in TRX Command.
- Creating building maps in TRX Command would have been significantly more difficult to create if TRX had not provided previously generated maps. MNR evaluators noted that this gets easier with practice.
- The location of the sensor on one individual was moved from the hip to centered along the waist mid demonstration after a discussion on optimum placement.
- During the demonstration, one phone was using LTE and the other Wi-Fi for data transmission. The one on Wi-Fi had disconnected a couple of times. MNR evaluators also had to disable the connection to other Wi-Fi in the surroundings that it would sporadically connect to.
- The project team had planned on using debug markers as per a suggestion by TRX Systems. This would create an easy reference for usage after the demonstration. However, this feature did not work after multiple attempts at the start of the demonstration.

Two-Dimensional Location Data Accuracy

- Manual corrections (which were referred to as “check-ins” by both NUSTL and MNR during the demonstration) resulted in significantly more accurate location data. This is appropriate for scientific applications such as the MNR emergency preparedness environmental survey.
- It was noted that the margin of error expanded significantly in a very short time if a proper initialization and regular manual corrections were not performed. The margin of error grew up to an estimated 200 feet during the third use case.
- Reference beacons greatly improved accuracy without the need for manual corrections.

Three-Dimensional Location Data Accuracy

- The TRX NEON Personnel Tracker regularly represented users on the correct floor of the building.
- The transition between floors resulted in clearer tracks when using stairs rather than an escalator. The use of an elevator also worked well.
- In one instance, a manual correction on the balcony caused the system to misplace the wearer as on the ground outside the building.
- Upon exiting the elevator to MNR offices, both wearers were shown on the wrong level at one point. While the cause is unknown, the project team hypothesized that this was due to an incorrect barometric measurement or radio frequency interference.

- It was anticipated that the TRX NEON Solution would self-correct, improving accuracy after about ten steps outside the elevator. However, the system did not self-correct and a manual correction was necessary.

Mobile Application Usability

- MNR evaluators mentioned a desire for the “center user” button (i.e., the button that centers the map on the user’s location) to be more intuitive in the mobile application. An intuitive center user button would allow TRX NEON Personnel Tracker wearers to track themselves and gain an awareness of their location on scene more easily. MNR evaluators suggested adding more explicit labeling, rearranging the buttons on the mobile app, or positioning the center user button next to the “north up” button (i.e., the button that reorients the map so that north is up).
- Other than the center user button, the mobile application was intuitive and easy to use. It was easy to see changes in location data accuracy represented by the error bubble.
- Both MNR and NUSTL observed that the frequency of manual corrections necessary for accurate location data may not be appropriate for quicker paced emergency response operations. First responders may not have easy physical access to paired smartphones while wearing personal protective equipment or operating other equipment. Additionally, use of the mobile application to perform a manual correction may distract from the tasks at hand. However, use of reference beacons instead of manual corrections would be more appropriate for emergency response operations.

3.2 Requirements Analysis

This section details how the TRX NEON Personnel Tracker performed against the requirements defined in Section 1.3 during the demonstration. One of the following determinations was given for each requirement:

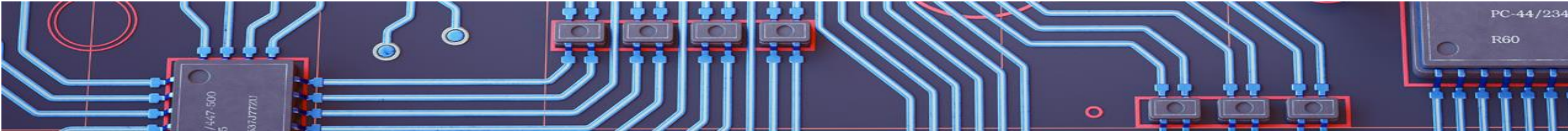
- **Fully Met**: The TRX NEON Personnel Tracker meets all parts of the requirement definition
- **Partially Met**: The TRX NEON Personnel Tracker meets some but not all parts of the requirement definition
- **Not Met**: The TRX NEON Personnel Tracker does not meet any part of the requirement definition
- **Insufficient Data**: Not enough data was collected during the demonstration to determine whether the TRX meets this requirement (may be combined with Partially Met or Not Met)
- **Did Not Evaluate**: This requirement was not evaluated during the demonstration

Overall, the TRX NEON Personnel Tracker fully met 14 out of 20 of the overall project requirements for location trackers, partially met one requirement and did not meet two requirements. Insufficient data was collected to make a determination on three requirements. While available data demonstrated that the TRX NEON met parts of the definitions of these requirements, it did not demonstrate that the device fully met the requirements. An additional five requirements were developed but were not evaluated during the technology demonstration. These requirements included the placement of reference pins, manual corrections while post-processing data, and data integration with other sensors and situational awareness displays.

The first group of requirements addressed location tracking capabilities and data accuracy. The project team evaluated four of these requirements found that the TRX NEON Personnel Tracker fully met all four. An additional two requirements in this group were not evaluated.

Table 3-1 Location Tracking Requirements

Req. No.	Requirement	Determination	Justification
1.1	GPS-Enabled Accuracy	Fully Met	Location trackers provided outdoor location tracking in GPS-enabled areas and met the accuracy requirement of three meters when initialization and check-ins were performed to maintain accuracy.
1.2	GPS-Denied Accuracy	Fully Met	Location trackers provided location tracking in GPS-denied areas and met the accuracy requirement of ten meters when initialization and check-ins were performed to maintain accuracy.
1.3	Three-Dimensional Accuracy	Fully Met	Location trackers provided three-dimensional location tracking on routes with elevation changes and met the accuracy requirement of three meters when initialization and check-ins were performed to maintain accuracy.
1.4	Beacons for Improved Accuracy	Fully Met	TRX NEON tracking units can use stationary Ultra-wideband (UWB) or Bluetooth low energy (BLE) beacons. Third party beacons were not available during the demonstration and three NEON trackers were deployed as beacons for the user operating a fourth tracking unit. Using the TRX NEON tracking units as beacons improved location tracking and reduced the need for manual check-ins.
1.5	Reference Pins	Did Not Evaluate	Reference pins were not placed at any location for retroactive reference.
1.6	Manual Data Correction	Did Not Evaluate	The TRX Command software was displayed in the video conference meeting. No manual corrections of previously recorded data were attempted during the demonstration. However, the software automatically corrects and adjusts displayed tracks while the tracking unit is in use.



The second group of requirements addressed wireless communications between the location tracker, the sensor platform, and data servers. The project team found that the TRX NEON Personnel Tracker met five out of six requirements regarding communications. Available data proved that the TRX NEON Personnel Tracker meets parts of the sixth requirement but did not prove that it fully meets the requirement.

Table 3-2 Communications Requirements for Location Trackers

Req. No.	Requirement	Determination	Analysis
2.1	Communications with Sensor Platform	Fully Met	Location trackers and sensor platforms (smartphones) were supported by a wireless personal area network (WPAN). One smartphone was operated through LTE and the other Wi-Fi for data transmission.
2.1.1	WPAN Connection Duration	Fully Met	WPAN connection between location trackers and sensor platforms was maintained over 95 percent of the duration of the operation and only minimal disruptions were experienced. One smartphone was operated through LTE and the other via Wi-Fi for data transmission. The phone on Wi-Fi experienced short disconnections and connected to other available Wi-Fi in the area before disabling other Wi-Fi networks.
2.1.2	WPAN Disruption Notification	Fully Met	Users were provided with a notification upon disconnection between the TRX NEON and the smartphone.
2.2	Communications with Server	Fully Met	Sensor platforms successfully and reliably transmitted data to servers over LTE and Wi-Fi networks throughout the demonstration.

Req. No.	Requirement	Determination	Analysis
2.3	Data Caching	Insufficient Data/ Partially Met	Due to an oversight, no data was collected on the ability of the TRX NEON to cache data on the tracker in the case of a WPAN disruption or to cache data on the sensor platform in the case of an external network disruption. During the debrief, TRX Systems representatives mentioned that the TRX NEON caches some data in the event of a disconnection between the sensor and the smartphone. However, there is no available data to prove that the TRX NEON Personnel Tracker fully meets this requirement.
2.4	Update Intervals	Fully Met	TRX NEON location data is updated by the sensor and on the mobile application at one-second intervals when movement is sensed. Data is updated at three-second intervals when the user is stationary. Data is updated at the same rate on the TRX Command software as well.

The third group of requirements addressed the integration of location data with data from other sensors and the displaying of this data on third-party situational awareness displays. The project team notes that the four requirements regarding data integration could not be properly assessed during this demonstration as originally intended. Three requirements were not evaluated. Available data proves that the TRX NEON Personnel Tracker partially meets the fourth requirement but cannot prove that it fully meets the requirement.

Table 3-3 Data Integration Requirements for Location Trackers

Req. No.	Requirement	Determination	Analysis
3.1	Data Integration	Did Not Evaluate	This requirement was removed from consideration for assessment in the demonstration. The development of an approach to integrate the data prior to the event was attempted but was unsuccessful. It will be revisited post factum. At the time of the demonstration it was not deemed an option.
3.1.1	FEMA CBRNResponder Integration	Did Not Evaluate	This requirement was removed from consideration for assessment in the demonstration. See analysis for 3.1, above, for more details.
3.1.2	ESRI ArcGIS Integration	Did Not Evaluate	This requirement was removed from consideration for assessment in the demonstration. See analysis for 3.1, above, for more details.
3.2	Data Storing	Insufficient Data/ Partially Met	Location data during the demonstration was recorded. While the data can be played back on TRX Command, this was not tested on other situational awareness software. Additionally, as noted in the analysis for requirement 3.1 integration of the TRX NEON data with other sensors (particularly the Ludlum 3001) was not conducted during the demonstration.

The fourth group of requirements addressed human factor issues and the ability for wearers to use the location tracker without inhibiting the ability to manage other responsibilities. The project team found that the TRX NEON Personnel Tracker fully meets two out of three location tracker requirements regarding human factors. The TRX NEON Personnel Tracker does not meet the third requirement.

Table 3-4 Human Factor Requirements for Location Trackers

Req. No.	Requirement	Determination	Analysis
4.1	Interference Prevention	Fully Met	The TRX NEON tracker did not interfere with the wearers' ability to conduct other job-related tasks.
4.2	Mobility	Fully Met	The TRX NEON tracker did not inhibit the wearers' mobility.
4.3	Deactivation	Not Met	The TRX NEON tracker can be deactivated or unpaired from the smartphone by pressing and holding a large button on the tracker itself. It should be noted that because the user is required to press and hold the button, rather than just pressing the button, unintentional deactivations may be reduced.

The fifth group of requirements was categorized as a miscellaneous group. The project team found that out of six requirements in this group, the TRX NEON fully meets three requirements, partially meets one requirement and does not meet one requirement. The project team did not have enough data to demonstrate that the TRX NEON fully meets a sixth requirement. However, available data proves that the TRX NEON partially meets this requirement.

Table 3-5 Miscellaneous Requirements for Location Trackers

Req. No.	Req.	Determination	Analysis
5.1	Colocation with Other Equipment	Fully Met	The TRX NEON Personnel Tracker can be mounted on the body via a belt clip or in a pouch. The small size of the TRX NEON TU allows for other equipment to be mounted on the body. Figure 3-1, below, depicts the mounting position that was used by evaluators during the demonstration.
5.1.1	Integration with Other Hardware	Not Met	The TRX NEON itself is not currently integrated with other hardware, such as other sensors or sensor platforms.
5.2	Time-Synchronization	Fully Met	The TRX NEON is automatically time-synchronized with the smartphone when it is paired. As such, the location tracker can be time-synchronized with other devices that are connected to the smartphone, such as a handheld radiation survey meter.

Req. No.	Req.	Determination	Analysis
5.3	Battery Life	Insufficient Data/ Partially Met	Two TRX NEON units remained active for two hours and 30 minutes at the start of the demonstration. One unit (serial number 9404) started the demonstration with 84% remaining battery life and had a remaining battery life of 55% prior to the lunch break. The other unit (serial number 9405) had started the demonstration with 83% battery life and had a remaining battery life of 49% prior to the lunch break. It should be noted that unit 9405 was used during the first use case, but unit 9404 was not. Unit 9405 was recharged during the lunch break for approximately one hour. Unit 9405 started at 97% and ended at 92% during the final use case. This was the only unit used during the final use case. It can be inferred that the TRX NEON tracker has a battery life of approximately eight hours when conducting regular manual corrections without the use of reference beacons, five hours when not conducting regular manual corrections and not using reference beacons, and 20 hours when using reference beacons but not conducting regular manual corrections. However, since the trackers were not allowed to run continuously under each operating condition without recharging during the demonstration, NUSTL cannot definitively prove that the TRX NEON fully meets this requirement. It should be noted that TRX Systems advertises an average battery life of eight hours. Battery capacity was most likely not degraded, as the TRX NEON trackers used during the demonstration were first activated during January 2021.

Req. No.	Req.	Determination	Analysis
5.4	External Power Source	Fully Met	The TRX NEON TU is charged via a micro-USB 2.0 port. Evaluators were equipped with portable USB power banks during the demonstration. However, the portable power banks were not used.
5.5	Reconnection	Partially Met	Evaluators performed power cycles on the TRX NEON TUs throughout the demonstration to intentionally disrupt communications between the TRX NEON TU and the smartphone. The connection was automatically re-established once the TRX NEON TU was powered on. In most instances, the connection was re-established in less than ten seconds. However, re-establishing the connection could take up to 30 seconds. No notification of disrupted communication was provided to evaluators.

Figure 3-1 TRX NEON mounting positions used by MNR evaluators

4.0 CONCLUSION

On March 26, 2021, NUSTL and MNR conducted a semi-virtual technology demonstration of the TRX NEON Personnel Location Tracker technology. MNR conducted the demonstration on site at GCT in New York City, NY, while NUSTL and representatives from TRX Systems attended virtually via a video conference bridge. During the demonstration, MNR and NUSTL conducted five location tracking use cases including:

- Single user, GPS-enabled tracking;
- Multiple user, GPS-enabled tracking;
- Multiple user, GPS-denied tracking;
- Multiple user, three-dimensional tracking; and
- Single user, beacon-assisted tracking.

Evaluators found that the location data accuracy provided by the TRX NEON was sufficient for scientific usage if a proper initialization was performed and either regular manual corrections were made or reference beacons were deployed. Evaluators noted that reference beacons, rather than manual corrections, may be more appropriate for emergency response operations, as the frequency of manual corrections necessary to produce accurate data may distract from the task at hand.

After the demonstration, NUSTL determined the TRX NEON fully met 14 out of 20 requirements for location trackers, partially met one requirement, and did not meet two requirements. Insufficient data was collected to make a determination on three requirements.

While available data proved that the TRX NEON met parts of the definitions of these requirements, it could not prove that the device fully met the requirements. An additional five requirements were developed but were not evaluated during the technology demonstration. These requirements included the placement of reference pins, manual corrections while post-processing data, and data integration with other sensors and situational awareness displays.

4.1 Next Steps

Following the demonstration, MNR used the TRX NEON to conduct an emergency preparedness environmental survey of GCT. By time-synchronizing the TRX NEON with environmental sensors, the goal is to have MNR be able to attribute environmental measurements to specific locations in GCT and generate maps that can be used in situational awareness platforms, such as ESRI ArcGIS or FEMA CBRNResponder.

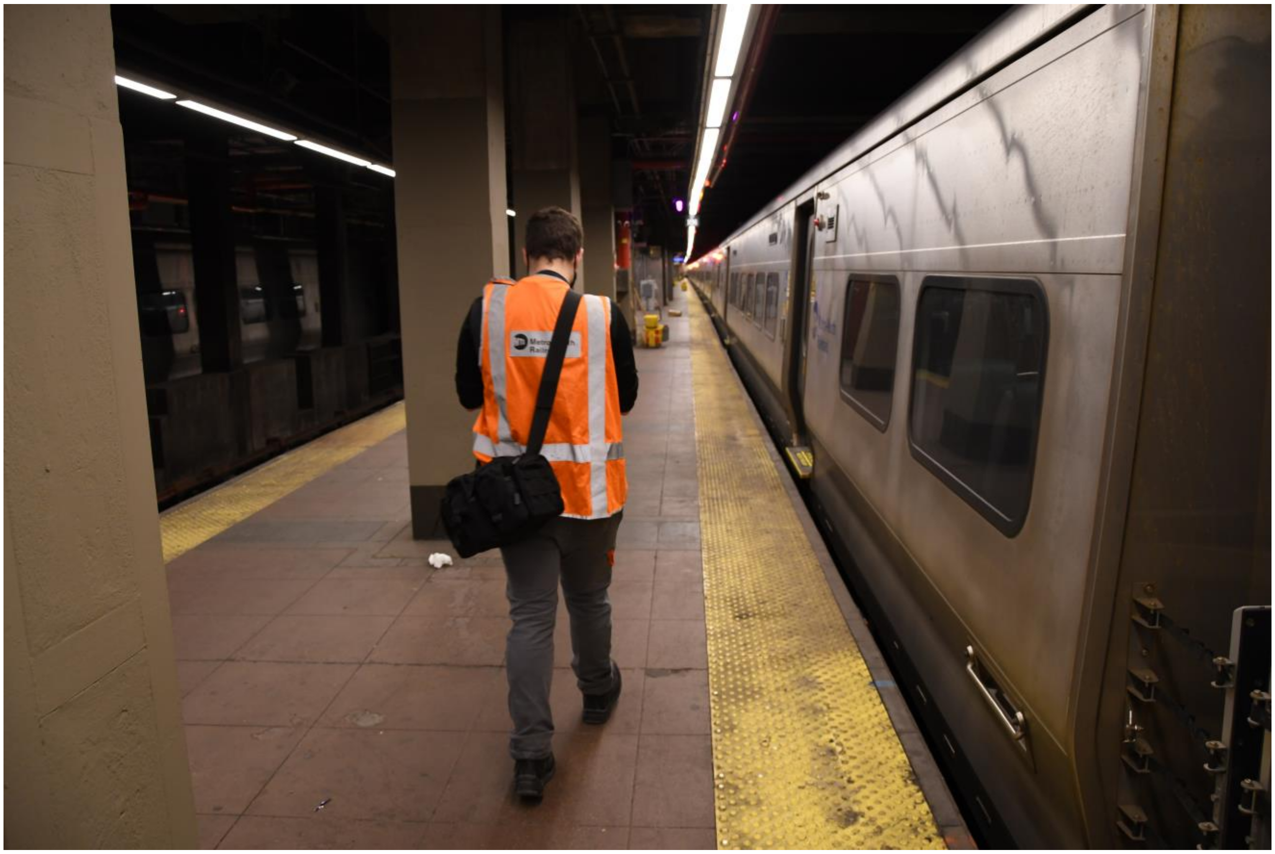


Figure 4-1 MNR employee collecting data for environmental survey

A Ludlum 3001 survey meter is placed in the messenger bag.

5.0 APPENDIX A: DATA COLLECTION PROMPTS

This section includes data collection prompts that were compiled by NUSTL prior to the demonstration. Due to the semi-virtual nature of the demonstration, there was a need for regular verbal interactions between NUSTL and MNR to record observations on technology performance. These questions were treated as recommended topics to discuss during the demonstration to solicit feedback from MNR evaluators, rather than a formal survey in which questions required an answer. As previously mentioned in this report, TRX Command testing activities as well as data integration and analysis were not conducted during the technology demonstration.

Technology Installation:

Write down the serial numbers of the devices you are assigned. This should include the TRX NEON, the Android phone and any Smart Beacons you are holding.

How long did the overall setup process take? How long did it take to install software; to pair TRX NEON devices with Android phones; to synchronize clocks across all equipment?

TRX NEON Testing:

Are you able to use TRX mobile applications to verify your locations? Are you able to verify your location in three dimensions?

What is the approximate accuracy of the location data? Is above-ground accuracy within three meters? Is below ground accuracy within ten meters? Is three-dimensional accuracy within three meters?

Are TRX mobile applications correctly representing your bearing?

Report when communications between any component of the system is dropped. This includes the link between the TRX NEON and the Android phone, and the link between the Android phone and the TRX data server.

What happens when communications are re-established between the TRX NEON and the Android phone? Does the TRX NEON restart automatically? Is historical data cached on the TRX NEON and re-transmitted to the phone?

Are you aware of any other users losing connection? Does the TRX software provide a push notification when any users (including yourself) lose connection? Is any location data missing from other users?

Are you able to drop a pin and/or add notes to it? Can you see pins dropped by other users?

TRX Command Testing:

Does the TRX software provide a comprehensive representation of each user's location? This includes three-dimensional locations as well.

Does the TRX software correctly represent NEON users' bearings?

Is the user interface of the TRX software intuitive and easy to use?

What is the approximate accuracy of the location data? Is above-ground accuracy within three meters? Is below ground accuracy within ten meters? Is three-dimensional accuracy within three meters?

Are you aware of any users losing connection? Does the TRX software provide a push notification? Is any location data missing from other users?

What happens when connection is re-established? Is missing data received in the TRX software?

Does it seem that data is being transmitted in real-time? Do you notice any lag or latency in the data?

Can you see pins dropped by TRX NEON users? Can you read any notes they added?

Data Integration and Analysis:

Can you easily attribute radiation measurements to specific locations? Can you use this to support the indoor radiation survey?

Can you access metadata from the TRX NEON and add notes? What types of metadata can you review?

Is manual correction of location data generated by the TRX NEON necessary? Can you create a backup of the data before correction?

What data points can you correct? Two-dimensional location? Three-dimensional location? Bearing? Time?

6.0 APPENDIX B: DEBRIEF QUESTIONS

The questions listed in this appendix were used to guide the debrief session at the end of the demonstration. It should be noted that some TRX Command testing questions were skipped during the debrief. Technology installation and TRX Command testing activities were conducted by MNR prior to the demonstration. Data integration and analysis activities were not performed during the technology demonstration and as such, these questions were skipped during the debrief. Responses given by evaluators during the debrief are on file with NUSTL and were used to generate this report.

Technology Installation:

Was technology setup easy? This includes pairing TRX NEON devices to Android phones, installing TRX software, synchronizing clocks, mounting the TRX NEON devices and using external power sources.

What challenges, if any, did you have while setting up the technology for the demonstration?

Was the length of time required to set up the technology okay?

TRX NEON Testing:

How accurate was the location data provided by the TRX NEON? Three-dimensional accuracy? Bearing accuracy? Was it accurate enough to support your mission?

Did you find the TRX mobile applications intuitive and easy to use? What changes to the user interface would you recommend?

Was the TRX NEON device uncomfortable to wear? Did it get in the way of your regular duties?

Was it easy to drop pins? Could you add notes? Were you able to see pins other users dropped?

Was it easy to place and activate beacons? Did the beacons sufficiently improve location accuracy? Would you use the beacons to support the indoor radiation survey?

Outside of intentional disconnections, how often did you lose communications between the TRX NEON and the Android phone? Between the phone and the data server?

Did the battery life last the duration of the demonstration?

TRX Command Testing:

How accurate was the location data provided by the TRX NEON? Three-dimensional accuracy? Bearing accuracy? Was it accurate enough to support your mission?

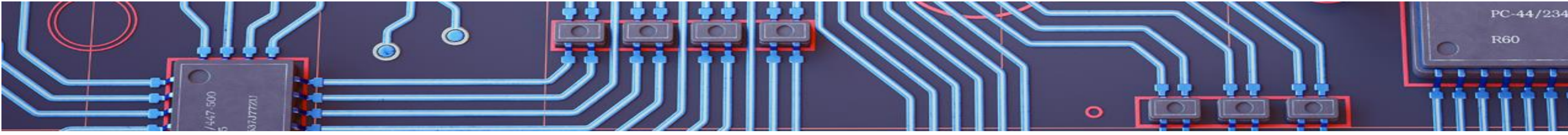
Were you able to determine where beacons were placed?

Was there any lag or latency in location data when received by the TRX Command software?

Were you able to see pins dropped by TRX NEON users? Were you able to access notes associated with each pin?

Did you find the TRX Command software intuitive and easy to use? What changes to the user interface would you recommend?

Outside of intentional disconnections, how often did you notice dropped communications? Was any data missing as a result?



Data Integration and Analysis:

Was it easy to create a data feed or map layer for ESRI ArcGIS with TRX location data and Ludlum radiation data? FEMA CBRNResponder?

Will you be able to use this data integration to support the indoor radiation survey?

Do you think it would be easy to integrate TRX data into other third-party platforms (e.g., Android Tactical Awareness Kit (ATAK))?

Was there any need for manual data correction? Were there any challenges you experienced when correcting data?