Pendar X10 Handheld Standoff Raman Spectrometer

Technology Report

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FOREWORD

The U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) Urban Operational Experimentation (OpEx) 2022—hosted in July 2022 by the OpEx Program and National Urban Security Technology Laboratory (NUSTL)—provided first responders with the opportunity to experiment with new and emerging technologies in realistic, urban settings. This event combined demonstrations of leading-edge technologies with application-based field assessments staged throughout the New York City metropolitan area.

Urban OpEx 2022 was an important opportunity for DHS S&T to better understand the operational needs and requirements of urban first responders. Additionally, this event enabled first responder agencies to assess new technologies and provide feedback to participating technology vendors. Urban OpEx 2022 included participation from a broad range of federal, state, local, and private sector partners.

As part of the preparation for this event, DHS S&T facilitated discussions with first responder agencies to identify existing capability gaps. In coordination with NUSTL, the OpEx Program developed a Request for Information in light of these capability gaps soliciting interest from technology vendors who addressed the current needs, interests, and priorities of first responder organizations. DHS S&T selected technologies, in collaboration with first responder stakeholders, for participation in Urban OpEx 2022. Urban OpEx events enrich the homeland security enterprise by gathering SMEs as first responder evaluators to train on and assess emerging technologies.

First responder evaluators provided recommendations and feedback to technology vendors that can inform the refinement of existing technologies. Evaluator recommendations also provide valuable insight for the national first responder community to inform investments in new and emerging technologies.

For more information on Urban OpEx 2022 or to view additional Urban OpEx reports, visit www.dhs.gov/publications-library/science-and-technology.

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EXECUTIVE SUMMARY

On July 19, 2022, the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) conducted Urban Operational Experimentation (OpEx) 2022, during which participants evaluated the Pendar X10 (hereafter referred to as "X10"), a handheld standoff Raman spectrometer[1]. Developed by Pendar Technologies, X10 can identify military, industrial, and homemade explosives; drugs; chemical warfare agents; toxic chemicals, related precursors and byproducts; and other organic or inorganic materials in a wide range of law enforcement and emergency response applications.

During Urban OpEx 2022, first responder evaluators used X10 in an operational scenario to provide feedback on its features and functionality for urban first responder organizations. Participating responders came from a variety of New York City agencies, including the Metropolitan Transportation Authority, New York City Emergency Management, New York City Fire Department, and New York City Police Department, as well as first responder members from the DHS S&T First Responder Resource Group,[2] including the Oswego (NY) Fire Department and San Diego (CA) Fire and Rescue. A Pendar Technologies product engineer presented X10's features and capabilities. Evaluators experimented with X10 through a series of single and multiple chemical identifications. The Urban OpEx 2022 Planning Team incorporated first responder input to develop a list of critical tasks for evaluators to accomplish while operating X10. The Urban OpEx Planning Team also encouraged first responder evaluators to consider other use-cases or environments outside the identified critical tasks that they might use the technology during an actual event or incident.

Evaluators found the X10 hardware intuitive and the display screen easy to read. They were also impressed by X10's ability to scan unknown substances up to six feet away without causing an unintentional ignition. The evaluators identified the ability to perform standoff detection and identification of hazardous substances as a significant potential mission improvement for first responders due to its increase of responder safety.

Evaluators faced several challenges when operating X10 related to the equipment's ergonomics: the uneven weight distribution of the device and the possible difficulties of trying to press and hold the buttons when suited up in hazardous materials (HAZMAT) gear. X10 proved difficult to hold steady and was challenging to attach quickly to the tripod. The evaluators determined that X10 could improve HAZMAT and explosive ordnance disposal operations but needs improvements to its usability. One ease of use limitation for this type of technology is the need to auto-focus the laser to correctly identify certain chemicals, a process that currently has some challenges in executing rapidly and reliably.

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[1] Raman spectroscopy analyzes a sample chemically, by using light to create (excite) molecular vibration and interpreting this interaction to identify specific molecules present in the sample.

[2] First Responders Resource Group is an all-volunteer working group comprised of 120 experienced emergency response and preparedness professionals (active and retired) who help S&T maintain focus on the top priority needs of responders in the field, helping to guide its research and development efforts.

The X10 currently requires the end user to focus the X10 laser on an unidentified substance. More complex substances like honey require more time holding the focus button for the X10 to correctly identify the substance, which can be a challenge. One suggestion is an improved auto-focus feature that would be more robust in its automation of stepping through various focal lengths. Another concern with the current system's usability is that first responders who wear heavy protective equipment might have trouble performing the auto-focus function reliably to test certain substances. Additionally, first responders indicated that a more even weight distribution would support their ability to use the auto-focus feature and increase their maneuverability with the X10 when operating in HAZMAT personal protective equipment.

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1.0 INTRODUCTION

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) supports first responders in their mission to protect the public by introducing them to new products and tools that enhance their operational effectiveness. The DHS S&T Operational Experimentation (OpEx) Program partnered with the National Urban Security Technology Laboratory (NUSTL) to plan, conduct, and assess Urban OpEx 2022.

To identify technologies with the highest utility for emergency response personnel, urban first responders from the Metropolitan Transportation Authority (MTA), New York City Emergency Management (NYCEM), New York City Fire Department (FDNY), and New York City Police Department (NYPD), identified capability gaps in their work and technology topic areas that could help to mitigate those gaps.

Using this input, the Urban OpEx Planning Team identified technology topic areas to address the first responders' capability gaps. DHS S&T then developed and disseminated a Request for Information (RFI) to solicit responses from vendors who offer products in those technology areas. Table 1 highlights Urban OpEx 2022 technology topic areas included in the event.

Table 1: Urban OpEx Technology Areas

Topic Area	Description
Fixed, On-body or Handheld Sensors	Fixed, on-body, or handheld technology solutions that can send and receive sensor data to support and enhance first responders' mission effectiveness.
Unmanned Aircraft Systems (UAS)	UAS technology solutions that provide the capability to survey and model urban environments.
Situational Awareness Platforms	Situational awareness technology solutions that provide necessary information to first responders to enhance disaster and emergency preparedness and response capabilities.
Deployable Robotics	Technology solutions that provide deployable robotics capabilities to support or enhance first responders' mission effectiveness.
Deployable Communications Systems	Technology solutions that provide deployable communications capabilities for use during an emergency or disaster, restoring failed communications systems or augmenting existing ones to increase capacity for emergency response functions.
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., bags left behind), behavior threat detection (e.g., thoughtcrime, crimes in progress, people in need of assistance), and facial recognition.

DHS S&T used technology areas to guide the selection process in consultation with subject matter experts (SMEs) from within S&T, leading to the Urban OpEx Planning team selecting seven technologies out of more than 50 RFI responses. The Urban OpEx Planning Team then worked with first responders, emergency response personnel, and technology developers to develop operational scenarios and select venues for staging the experiments. In addition to scenario development, the Urban OpEx Planning Team created an Experimentation Plan (ExPlan) to guide the event. The ExPlan included information about logistics, safety, roles and responsibilities, experimentation design and scope, and evaluation guidance. Hosted by the OpEx Program and NUSTL, from July 19 to 22, 2022, New York first responder agencies and members of the DHS S&T First Responder Resource Group (FRRG)[3] experimented with the technologies and provided feedback and observations to inform technology development.

On July 19, 2022, seven first responder evaluators used the Pendar X10, a commercial off-the-shelf (COTS) handheld standoff Raman spectrometer[4] as a part of Urban OpEx 2022. SMEs from FDNY, MTA, and NYPD participated as evaluators to assess X10's utility for their respective agencies. Observers included the Port Authority of New York and New Jersey (PANYNJ) and various federal, state, and local partners also attended. Pendar Technologies participated in Urban OpEx 2022 under a Cooperative Research and Development Agreement (CRADA) with DHS S&T.

1.1 PURPOSE

The Urban OpEx Planning Team designed the X10 operational experiment to provide first responders and emergency response personnel with an opportunity to learn about X10's capabilities and limitations, gain hands-on knowledge in a representative environment, and demonstrate X10's use in various applications. First responder evaluators gave feedback that could be used by Pendar to improve the X10 product. Likewise, the feedback gave S&T program managers a better understanding of first responder and emergency response personnel needs to help guide future S&T investments.

1.2 OBJECTIVE

Urban OpEx 2022 will introduce new technologies and assess their ability to address first responder mission capability needs.

- Objective 1: Share end-user feedback on X10 with the national first responder community to inform their decision-making
- Objective 2: Share first responder feedback with Pendar to improve their products

[3] First Responders Resource Group is an all-volunteer working group comprised of 120 experienced emergency response and preparedness professionals (active and retired) who help S&T maintain focus on the top priority needs of responders in the field, helping to guide its research and development efforts.
[4] Raman spectroscopy analyzes a sample chemically, by using light to create (excite) molecular vibration and interpreting this interaction to identify specific molecules present in the sample.

1.3 RESPONDER CAPABILITY NEED

The use of household and industrial chemicals in attacks on the public exemplifies the importance of handheld chemical hazard detectors. First responder SMEs who advised the Urban OpEx Planning Team on capability gaps indicated that fixed, on-body, or handheld sensors could augment their ability to send and receive sensor data to support and enhance mission effectiveness during an emergency. This technology will streamline the identification of unknown substances while protecting urban first responders from potentially dangerous chemical hazards during a major event or disaster.

1.4 SCOPE

Due to the time constraints and scenario limitations, evaluators and the Urban OpEx Planning Team could not experience all of X10's features, capabilities, and configurations at Urban OpEx 2022. Technology training was limited to one hour of virtual training before Urban OpEx and one hour of in-person training at the event, which may have constrained how the evaluators interacted with the technology.

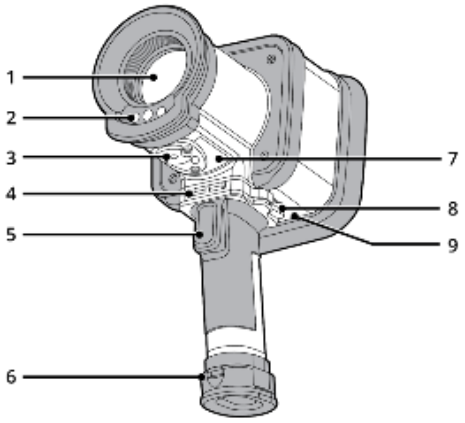
1.5 PRODUCT DESCRIPTION

The X10 (Figure 1) is a handheld Raman spectrometer measuring 11.5 x 10.5 x 5.5 inches and weighing six pounds. It uses a laser to scan unknown substances--liquid, gel, or solid samples--and compares them to a library of over 4,000 chemical identifiers in under 30 seconds. The device can measure through plastic bags, fume hood sashes, car windows, and windshields, allowing the user to keep a safe distance from potentially toxic materials. This product is not intended to be used to detect trace amounts of chemical compounds, but instead is meant to detect and identify chemical compounds when there is a sufficiently large sample available to analyze.

Figure 1: Pendar X10 Analysis of Substance

The X10 has Wi-Fi, Bluetooth, and USB connectivity and uses PendarLink, a personal computer and Windows 10 compatible software. It requires no routine maintenance to remain operational other than charging and replacing its batteries.

Raman spectrometers use scattered light from a laser pointed at a chemical sample to identify the chemical(s) present. As light (in this case, a laser) interacts with a material or substance, it can be transmitted, reflected, absorbed, or scattered. The Raman scattering changes energy and frequency compared to the laser, which is then analyzed as a "fingerprint" to identify the chemical composition.



Item	Description
1	**Aperture:** The main telescope lens of the Pendar X10, used both as an output port for the Raman and two red aiming lasers and as a collection port for the measured Raman signal.
2	**Front Sensors:** Three small windows beneath the aperture protect the Front Sensors, which include a visible camera, an ambient light sensor, and a white LED light.
3	**Tripod Attachment Point:** The location to attach the tripod.
4	**Handle Attachment Rail:** Guides the handle onto the bottom plate of the Pendar X10.
5	**Trigger:** Turns on two red aiming lasers and initiates a scan.
6	**Lanyard Attachment Point:** Can be attached to the base of the handle for handsfree transport. A lanyard is not included with the Pendar X10.
7	**Safety Label:** Includes critical safety information for the Pendar X10.
8	**Handle Lock Lever:** Unlocks and locks the handle at the base of the Pendar X10.
9	**Product Details Label:** Includes compliance stamps and details about the Pendar X10.

Figure 2: Pendar X10 with Labeled Parts and Descriptions

Image credit: Pendar Technologies

The X10's compact handheld form (Figure 2) allows onsite screening in 60 seconds or less, including power-up and time to analyze. To analyze a substance, the user positions themselves no more than six feet away, points the X10 to the target substance, and presses a trigger to initiate two alternating lasers, which must be aligned to identify the position of the substance and scan it (see Figure 3). The user then waits no more than ten seconds for most results to appear on the screen (Figure 4) and 30 seconds for highly fluorescent or absorbent samples.

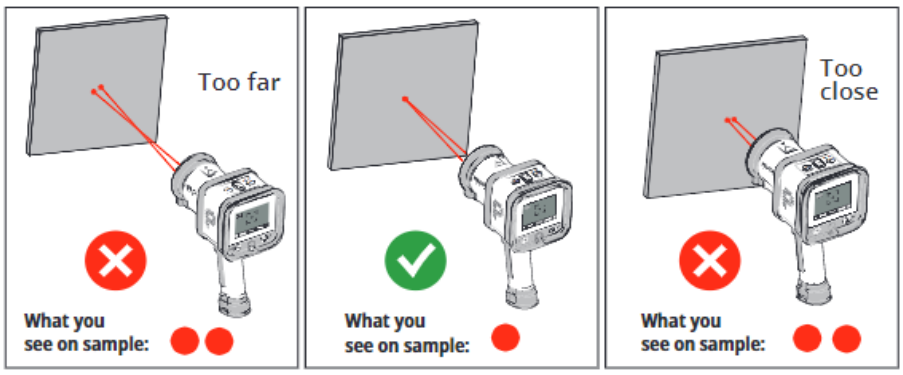


Figure 3: Focusing X10 Lasers

Image credit: Pendar Technologies

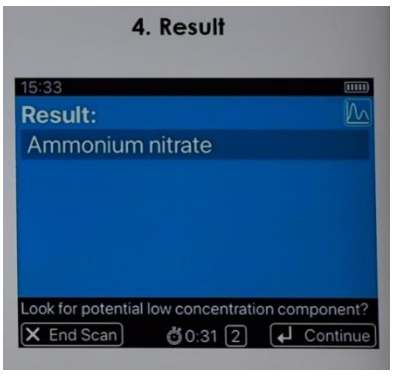


Figure 4: Pendar X10 Result Screen

Image credit: Pendar Technologies

2.0 EXPERIMENT DESIGN

The Urban OpEx Planning Team designed scenarios to allow first responders flexibility to experiment with features most relevant to their missions. Input from first responders, the technology vendor, the OpEx Program, and NUSTL's Experimentation Director helped develop scenarios that were not overly prescriptive but consistently engaged evaluators in testing the functionality of X10.

Scenario:

An explosion is detected at Randall's Island. First responders believe the building is contaminated, and there may be survivors trapped inside.

Critical tasks to perform while using X10 included:

- Identifying chemicals in lab-like and indoor environments
- Relaying detections and identified samples to incident command[5]

After evaluators completed the operational activities, the Urban OpEx Planning Team staged a debriefing to ask them to consider how this technology would affect their current standard operating procedures and whether it could be used to augment their response capabilities.

2.1 SUMMARY OF THE OPERATIONAL EXPERIMENT

Participants from FDNY, NYPD, NYCEM, MTA, and FRRG (see Table 2) convened at the FDNY Training Academy on Randall's Island, New York City, New York, to test and evaluate the Pendar X10. Ahead of the OpEx event, evaluators had the opportunity to participate in virtual technology training with vendors, allowing evaluators to have some familiarity with the technology ahead of time.

Activities began with a presentation from the OpEx Program, NUSTL, and FDNY that provided an overview of Urban OpEx 2022 and its purpose. The Experimentation Director provided additional opening remarks and a safety briefing.

Table 2: First Responder Evaluators for X10

First Responder Agency	Number of Evaluators
MTA	1
NYPD Counterterrorism	2
FDNY HAZMAT	2
Oswego Fire Department	1
San Diego Fire-Rescue	1

Figure 5: Experimentation Director Bhargav Patel Presents Opening Remarks

[5] Due to timing constraints, evaluators were unable to transmit detections and results to a mock incident command.

A Pendar Technologies technology vendor then trained participants on the capabilities of the X10. After 30 minutes of hands-on training with evaluators, the test activities began.

Evaluators operated the X10 in a training academy classroom to identify single-chemical compounds and multiple-chemical compounds. Evaluators practiced using the X10 as a handheld device and on the Pendar Technologies-provided tripod.

Six evaluators individually experimented with the X10. The test scenario focused on using the X10 to detect and identify single- and multiple-chemical compounds used to simulate chemical, biological, radiological, nuclear, and high-yield explosive (CBRNE) substances. The experiment gave first responders an opportunity to evaluate the ability of X10 to accurately detect and identify various chemical compounds that first responders may encounter in an emergency response. Table 3 summarizes the chemical compounds that were examined for this experiment. Two Pendar X10s were available for the experiment, and six chemical compounds were laid on a table in various containers.

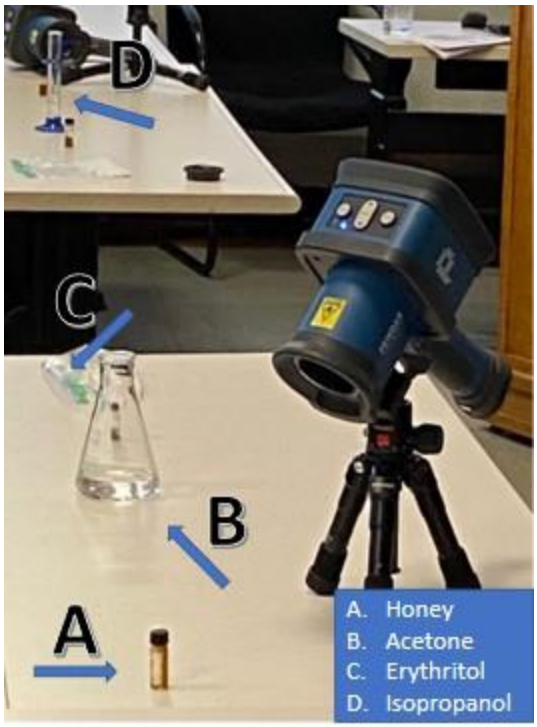


Figure 6: X10 on Tripod at Scanning Station (not all test substances are included in this figure)

Table 3: Sample Chemical Compounds Used

Chemical Compound	Commercial Off-the-Shelf Form	Container Material
Methyl Salicylate	Wintergreen Oil	Glass vial
Ammonium Nitrate	Instant Cold Pack	Plastic compress bag
Potassium Nitrate	Stump Remover Granules	Plastic bag
Erythritol	Stevia-based sweetener	Plastic bag
Potassium Permanganate	Filter Regenerant (pool supply)	Glass vial
Isopropanol	Rubbing Alcohol	Glass cylinder
Acetone	Nail Polish Remover	Glass beaker
Glycerin	Skin Moisturizer	Glass vial
Fructose/Sucrose/H_20	Honey	Glass vial
Acetylsalicylic Acid/Paracetamol/Caffeine	Headache Pain Reliever	N/A

2.1.1 CONDUCTING EXPERIMENTATION ACTIVITIES

The Urban OpEx Planning Team set up a lab-like scenario where evaluators would use the X10 and household chemicals for two tasks: identifying a single-chemical compound and identifying a multiple-chemical compound (Figure 6). Evaluators were instructed to conduct both tasks in succession, identifying single-chemical compounds and immediately moving along to identify a multiple-chemical compound.

2.1.2 FUNCTIONALITY

Evaluators used the X10 to detect different types of single- and multiple-chemical compounds to evaluate the instrument's:

- accuracy
- consistency
- results display

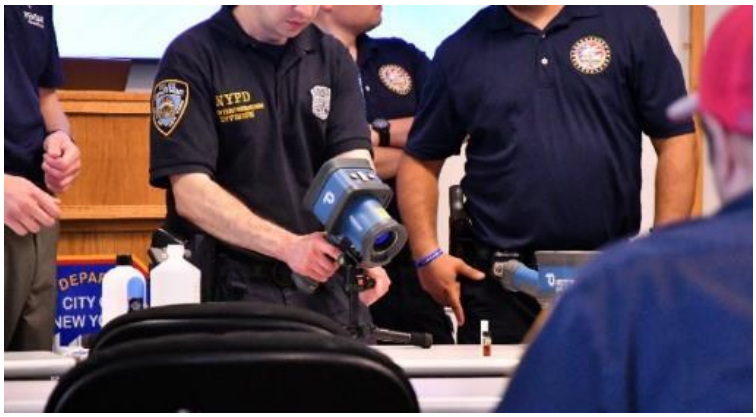


Figure 7: Evaluators Experiment with X10 on Tripod

Erythritol (sold commercially as Truvia) and acetone (in the form of nail polish remover) were single-chemical compounds tested during this experiment, among others listed in Table 3. The chemical state (e.g., solid versus liquid) of the sample impacted how evaluators needed to aim the X10 and the accuracy of the identification reports. Evaluators struggled to follow Pendar's instructions on aiming X10's lasers (Figure 3) into liquids, like acetone, and often received inconclusive results on their first scan. As shown in Figure 7, the laser needs to be aimed precisely so that both lasers overlap on the target up to a standoff distance of six feet.

Evaluators used the Pendar-provided tripod to steady the lasers and aim the device in advance of the analysis, freeing their hands to move the substance sample into the target focal point, a method that improved device accuracy. When evaluators still received inconclusive results despite using this approach, they were instructed to continue conducting scans until they received conclusive results. Pendar instructed evaluators how to use the autofocus feature during training and upon request during experimentation. The autofocus feature aided some responders with their scanning, but not every evaluator tested this feature.

Evaluators found a notable difference in the X10s capacity to produce conclusive results for multiple-chemical compounds. Testing the multiple-chemical compound, the headache pain reliever Excedrin, was similar operationally to testing single-chemical compounds in the same state of matter. Unlike the focusing method required for liquids, no modified or extra steps are required to scan and analyze the multiple-chemical compound.

However, when the X10 returned inconclusive results the device could indicate some chemicals in a multiple-chemical compound (see Figure 8), though it could not identify all chemicals, resulting in the inconclusive result.[6]

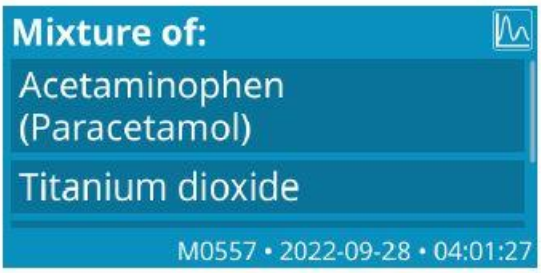


Figure 8: Result Screen for a Multiple-Chemical Compound

Image credit: Pendar Technologies

First responders using the X10 know they are likely to need multiple scans of the same sample in order to identify all present chemicals in a multiple-chemical compound. The specificity and accuracy of the X10's results for a multiple-chemical compound varied. A few evaluators had the experience of the X10 successfully identifying all chemicals in a multiple-chemical compound. In other cases, the X10 detected one chemical but listed only the class or category of the remaining chemical components. Evaluators noticed that Pendar Technologies' chemical library was missing critical ERG information for some chemicals. Some evaluators struggled to identify complex samples such as honey, which is a surrogate for compounds such as heroin, which may be encountered in real-world first responder situations. Due to the limitations and constraints of Urban OpEx 2022, evaluators were limited to testing the six substances provided by Pendar and therefore could not test the full breadth of the X10 library.

2.1.3 USABILITY

Evaluators assessed the technology's usability for first responders, including aspects such as, but not limited to:

- focus trigger pull
- grip
- screen display

During the assessment activities, evaluators remarked that the trigger pull, and grip were easy to use when not gloved. Evaluators did not test use of the X10 while wearing HAZMAT personal protective equipment (PPE). The X10's screen displayed information and results throughout the experiment. For most results, evaluators reported they could see the target distance, detection results, and Emergency Response Guidebook (ERG) hazard statement information displayed on the device screen (Figure 9).

[6] If some compounds are detected, and one or more compounds do not have a category or class, the sample result is inconclusive.

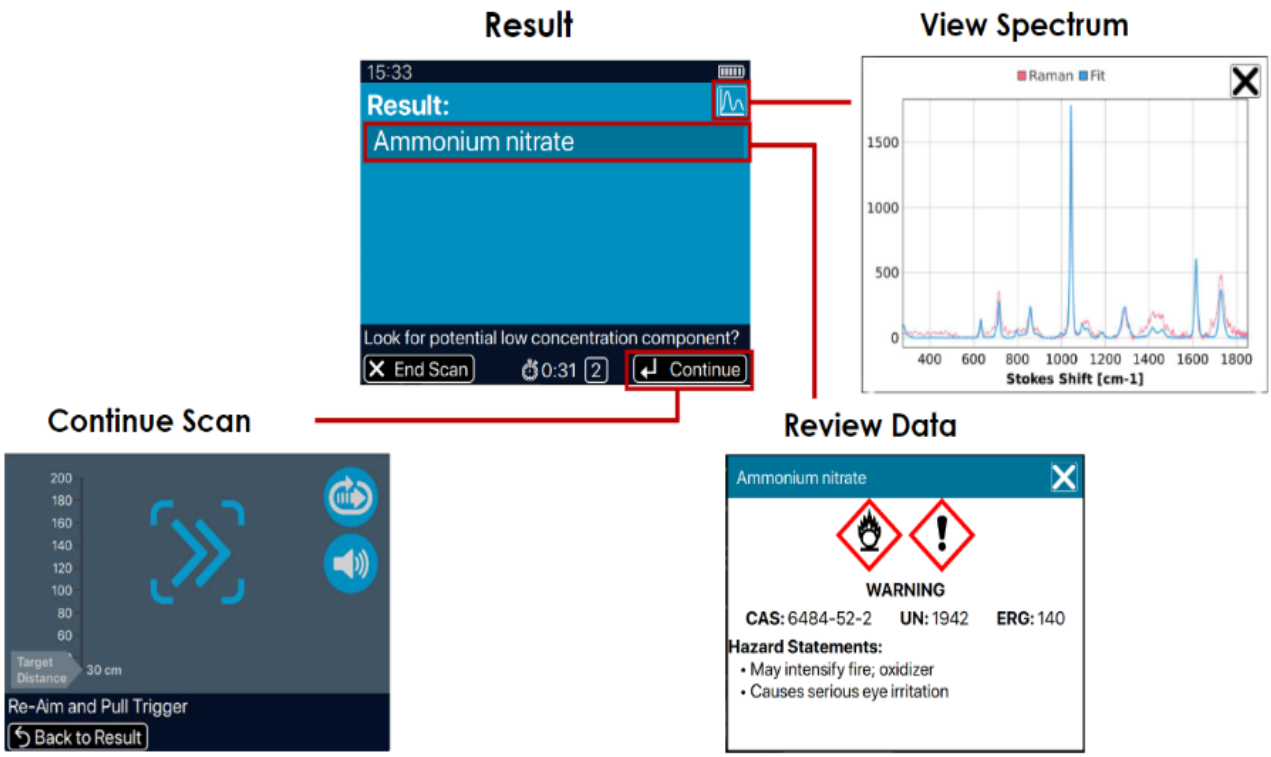


Figure 9: Pendar X10 Result Screens

Image credit: Pendar Technologies

2.2 DATA COLLECTION

Throughout the experiment, the Urban OpEx Planning Team also encouraged evaluators to voice their opinions to assigned data collectors. The Urban OpEx Planning Team and NUSTL obtained feedback from the evaluators in several ways:

- During the test activities, at least one data collector worked with each evaluator to record comments, concerns, and difficulties using Pendar X10
- After participating in the tasks, evaluators completed a questionnaire that captured their opinions on the functionality of X10 for first responders and emergency management
- Finally, the Experimentation Director led a technology debriefing during which evaluators provided additional comments and feedback that data collectors recorded. The discussion included the following questions:
  - In what applications do you anticipate using this technology?
  - What did you like about this technology?
  - What did you dislike about this technology?
  - What changes would you recommend? Why?
  - Is this technology something that you would actively use if it was available to you?
  - How do you think this technology would affect your ability to complete your duties?

3.0 RESULTS

The results for Urban OpEx 2022 evaluation of the Pendar X10 contain three types of feedback: questionnaire feedback, data collector notes, and technology debrief notes. These results will help first responder agencies understand whether X10 may be suitable for their operations and provide information to Pendar Technologies on strengths and opportunities for improvement for their technology. Each of the evaluators come from different domains, regions, specializations, and levels of experience (see Table 2 for a breakdown by disciplines). These diverse experiences give context to user feedback that may at times appear contradictory. However, most evaluators made similar evaluations to one another unless otherwise noted.

3.1 QUESTIONNAIRE FEEDBACK

Each evaluator completed a questionnaire on the functionality, ease of use, and most useful features. Part one of the questionnaire asked the evaluators to respond to a series of statements about X10's functionality for incident management missions and ease of use. Table 4 provides a breakdown of the responses. The number in each cell represents the total number of evaluators who selected one of the following answers when completing their evaluation: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree, or Unable to Determine.

Evaluators all agreed or strongly agreed that X10 could be used to help fulfill their agency's mission. A majority of the evaluators believed that X10 was an improvement over the technology they currently use. Evaluators unanimously agreed that the user interface was easy to engage with and understand.

Almost all evaluators recommend this technology for use by urban first responders while recognizing that it is best used by specialized task forces (e.g., HAZMAT) within first responder agencies and local organizations. However, when asked to consider its use by emergency response personnel wearing HAZMAT gear during an incident, evaluators indicated it may be challenging to operate the device due to bulky gloves and other equipment.

Figure 10: Evaluators Experimenting with X10

Some evaluators believe that the X10 has the potential to improve their ability to share information and coordinate chemical investigations between agencies or offices. While X10 is not explicitly designed for this purpose, first responders identified a few key changes that future models could adapt to make the technology more versatile, including Wi-Fi capability for data transfers.

Table 4: Evaluators' Questions on Suitability and Ease of Use

Equipment	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unable to Determine
This technology can help urban first responders' missions.	0	0	0	3	4	0
This technology is an improvement on the technology urban first responders currently use.	0	0	0	5	2	0
This technology performed all capabilities outlined by vendor	0	0	0	3	4	0
Responders are able to easily use this technology in conjunction with their required personal protective gear, if applicable to the scenario.	0	1	0	4	2	0
The display screen user interface was intuitive and easy to both understand and engage with.	0	1	0	1	5	0
The technology was easy to use with little to no interference from vendor during testing.	0	2	1	0	4	0
This technology increases urban first responder's ability to communicate and disseminate information during an event or incident.	0	2	0	2	2	1
This technology can improve first responder's ability to communicate and coordinate with other agencies and groups.	0	1	2	1	2	1
This technology can improve my ability to review and report information back to my leadership.	0	0	1	3	3	0
This technology should be recommended to other urban first responders.	0	2	0	3	2	0

Part two of the questionnaire asked evaluators open-ended questions to describe what features of X10 they found most useful and least useful. During the test activities, data collectors recorded evaluators' comments about positive attributes and challenges they experienced while operating the X10. After the tasks with the X10 were completed, the Experimentation Director led a debriefing to solicit further feedback from the evaluators. The collected feedback was solicited under four categories: the display screen, scanner/laser, Raman chemical identifier, and miscellaneous. Table 5 summarizes evaluator responses captured by data collectors during the experimentation and debriefing.

Given the evaluation of this product and the tasks presented, all evaluators believed that the X10 was an improvement over their current technology and agreed that it would be useful to their organization. Evaluators universally liked the display screen user interface and agreed that the most useful feature was the X10's standoff distance and its functioning without requiring that the responder make contact with chemical samples under detection. Evaluators complimented the screen's format and presentation of chemical information, especially the warning images for hazardous materials. The X10 identified the majority of samples quickly and correctly. The tripod was helpful in longer scans for complex samples such as honey, which is more difficult to scan because of its semi-liquid state. Evaluators had more success aiming and receiving conclusive results using the tripod.

Table 5: Evaluators' Responses to Questions on Features

Application	Strengths	Challenges	Recommended Changes
Display Screen	▪ Menu is clear and easy to navigate ▪ Touchscreen is very responsive; some evaluators believed it could be used with HAZMAT gloves ▪ No glare when standing out in the sun ▪ Navigating menus, selecting options, or handling controls is unaffected even for an evaluator with monochromatic vision	(None Identified)	▪ Add the ability to filter substances (either in the entire library or in the list of substances identified) ▪ Add chemical/compound pictographs ▪ Display the concentration of individual substances in a compound/mixed sample
Scanner/ Laser	▪ Standoff/non-contact feature ▪ Standoff distance was far enough to keep responders safe from chemical hazards ▪ Laser was easy to focus ▪ Laser did not ignite or otherwise alter substances during scanning	▪ Determining the correct standoff distance to scan chemicals was difficult ▪ Some evaluators had trouble aligning the lasers ▪ Manual alignment of the lasers could be challenging in a HAZMAT environment	▪ Use alternating lasers that blink at different intervals to become one non-blinking laser once focus is achieved
Raman Chemical Identifier	▪ Successfully scanned liquids in the demonstration ▪ Correctly identified chemicals, results came back within the 30-second timeframe advertised by the vendor* ▪ Able to detect multiple substances in a multiple-chemical compound*	▪ One sample returned a "poor quality" result three times (honey) ▪ One sample required three attempts before correct identification (acetone) ▪ Did not produce additional data, such as trace content on certain chemical compounds	(None Identified)

Application	Strengths	Challenges	Recommended Changes
Miscellaneous	▪ While top-heavy, the device is lightweight overall ▪ Easy trigger pull ▪ Autofocus feature was simple, intuitive, and helpful for difficult to scan samples ▪ The built-in library of over 4,000 chemical identifiers was useful ▪ Unverified substances can be sent to Pendar for further testing and added to the library upon verification ▪ Little calibration is required before operation ▪ Little training is required to operate	▪ Some users found the device difficult to hold steady due to uneven weight distribution (top-heavy) ▪ Difficult to lock into the tripod ▪ Autofocus feature took a long time ▪ Built-in library could be more comprehensive ▪ Device was slow to start up ▪ Buttons would be hard to push in HAZMAT gear	▪ Make it easier to expand the library ▪ Create a baseline for false positives ▪ Integrate with robots ▪ Design with more even weight distribution ▪ Include traceability in exported reports
** These items of feedback are valid and given by responders but do not describe the results of every responder who operated the X10*			

4.0 CONCLUSION

Evaluators' feedback on the X10 was generally positive. Throughout the written questionnaire and during the debrief session, evaluators reiterated that the X10 standoff capability and ease of use are positive attributes that would make them more likely to use it. The ability to perform standoff detection and identification of hazardous substances was identified as a major potential mission improvement because of its positive impact on the safety of first responders. Evaluators found that X10's ability to detect multiple substances within a compound would increase situational awareness during missions and enable first responder end-users to make more informed decisions.

Evaluators also noted some shortcomings that they encountered while experimenting with X10.

- The lasers proved challenging to align correctly to initiate a scan for some chemical samples in normal operational mode auto-focus mode
- Weight distribution was a limiting factor for the X10, as the top-heavy sensor negatively impacted evaluators' ability to point and aim the lasers at a substance steadily. Some evaluators speculated that this issue could be exacerbated when operating the device and using the auto-focus feature in specialized PPE and heavy HAZMAT gear.
- The distance from which to scan and detect substances successfully was difficult for evaluators to determine.

Evaluators offered recommendations to address these problems, including:

- Distribute weight more evenly Incorporate a solid laser once the alternating lasers are aligned

Some additional recommendations sought to extend X10's capabilities by integrating them with other technologies or tools used by first responders, more specifically integrating X10 with:

- Unmanned aircraft/ground vehicles (UAV/UGV)
- Wi-Fi for online transfer of data
- Expanded Emergency Response Guidebook libraries

The evaluators' feedback will be shared with Pendar Technologies, enabling the technology vendor to continue improving their product and potentially expanding the ways in which X10 could support first responders' work through more integration with other response tools. Urban OpEx 2022 experiments were conducted in a half-day timeframe and driven by tailored scenarios. Additionally, evaluators were only able to test the X10 in a controlled, lab-like environment. These factors limited the evaluator's exposure to a typical training program, and additional features/configurations of the technology not applicable to the test scenario and environment. Given these constraints, it is possible that some first responder evaluator feedback or suggestions for improvement could be addressed by potential users completing the entire technology provider-recommended training program.

5.0 ACRONYM LIST

Acronym	Definition
CBRNE	Chemical, Biological, Radiological, Nuclear, and High-Yield Explosive
COTS	Commercial Off-the-Shelf
CRADA	Cooperative Research and Development Agreement
DHS	Department of Homeland Security
ERG	Emergency Response Guidebook
FDNY	New York City Fire Department
FRRG	First Responder Resource Group
HAZMAT	Hazardous Materials
MTA	Metropolitan Transportation Authority
NYCEM	New York City Emergency Management
NYPD	New York City Police Department
NUSTL	National Urban Security Technology Laboratory
OpEx	Operational Experimentation
PANYNJ	Port Authority of New York and New Jersey
PPE	Personal Protective Equipment
RFI	Request for Information
SME	Subject Matter Expert
S&T	Science and Technology Directorate
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aircraft Vehicle
UGV	Unmanned Ground Vehicle
USB	Universal Serial Bus
X10	Pendar X10