CENTAUR Hybrid Network in a Box

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 to solicit interest from technology vendors who addressed the current capability gaps, 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 subject matter experts 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 provided 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 21, 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 TDCOMM CENTAUR Hybrid Network in a Box, hereafter referred to as CENTAUR. Developed by TDCOMM, CENTAUR is a rapidly deployable "network in a box" (NIB) cellular network platform designed to support first responders and emergency response personnel in deploying a mobile LTE network during operations where an LTE network is not available.

During Urban OpEx 2022, first responder evaluators assessed CENTAUR in an operational scenario to provide feedback on its features and suitability for urban first responder organizations. First responders from the New York City Emergency Management and the DHS S&T First Responder Resource Group[1], with representatives from Lubbock (TX) Fire Rescue, North Carolina Department of Information Technology, Oswego (NY) Fire Department, and San Diego (CA) Fire-Rescue Department, evaluated CENTAUR. The Urban OpEx Planning Team, incorporated vendor and first responder input to develop a list of critical tasks to accomplish while operating CENTAUR. TDCOMM product engineers presented CENTAUR's features and capabilities before evaluators operated CENTAUR to successfully deploy the NIB, set up and test mesh connections, and evaluate the signal strength and voice quality. The Urban OpEx Planning Team also encouraged first responder evaluators to consider ways other than the identified critical tasks that they might use the technology during an actual event or incident.

First responders appreciated CENTAUR's standalone capabilities and thought its variety of integrated bands and spectrums would serve well in urban environments, especially in situations without access to traditional communications networks. The strength of the network within the short-range tested during the scenario impressed evaluators. Some evaluators thought the physical CENTAUR equipment was easy to set up and use; however, most evaluators experienced a steep learning curve while navigating the technology in the limited time available. Some evaluators indicated that CENTAUR is not intuitive to learn and easily operate for non-expert users in communications technology. However, all but one evaluator indicated that CENTAUR could improve their ability to communicate during a multiagency response, share information, and coordinate with other agencies or groups because it establishes communication networks when otherwise unavailable.

Evaluators suggested improvements primarily concerned with ease of use, including simplified controls, a more straightforward node setup, and more clearly labeled buttons and toggles. Additionally, some evaluators were concerned that legal and regulatory barriers could limit the use of various CENTAUR capabilities.

[1] 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.

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1.0 INTRODUCTION

The U.S. 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 and technology areas that could help to mitigate those gaps.

Using this input, the Urban OpEx Planning Team identified technology 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. The Urban OpEx Planning Team surveyed technology vendors whose products could enhance operations for urban first responders. Table 1 highlights Urban OpEx 2022 technology 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., crimes in progress, people in need of assistance), and facial recognition.

The Urban OpEx Planning Team selected seven technologies for participation out of more than 50 RFI responses. DHS S&T used the Urban OpEx technology areas to guide the selection process in consultation with subject matter experts (SMEs) from within S&T. 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. New York City first responder agencies and members of the DHS S&T First Responder Resource Group (FRRG) experimented with the technologies and provided feedback and observations to inform technology development.

On July 21, 2022, seven first responder evaluators tested CENTAUR, a Network in a Box (NIB) developed by TDCOMM, during the Urban OpEx 2022 event hosted by the OpEx Program and NUSTL. SMEs from NYCEM and FRRG participated as evaluators to assess CENTAUR's utility for their respective agencies. Other attendees included observers from the NYPD, Port Authority of New York and New Jersey (PANYNJ), and various federal, state, and local partners. TDCOMM 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 CENTAUR operational experiment to provide first responders and emergency response personnel with an opportunity to learn CENTAUR's capabilities and limitations, experiment hands-on in a representative environment, and provide feedback about CENTAUR's application for first responders and emergency response personnel. First responder evaluators gave feedback that could be used by TDCOMM to improve its product. Likewise, the feedback gave S&T program managers with a better understanding of first responders and emergency response 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 CENTAUR with the national first responder community to inform their decision-making
- Objective 2: Share first responder feedback with TDCOMM to improve their products

1.3 RESPONDER CAPABILITY NEED

The uncertain and evolving nature of real-time emergencies and their aftermath underscore importance of deployable communication systems that increase situational awareness amongst emergency response personnel undertaking missions in degraded communications environments. Following a natural disaster, man-made disaster, or significant infrastructure failure, communication networks may be degraded or non-existent. First responder SMEs advising the Urban OpEx Planning Team on capability gaps indicated that deployable communication systems could enhance emergency responders' ability to execute complex missions in operating environments where communications networks are austere or degraded.

1.4 SCOPE

Due to time constraints and scenario limitations, evaluators and the Urban OpEx Planning Team may not have experienced all of the features, capabilities, and configurations of CENTAUR at Urban OpEx 2022. Technology training was limited to one hour of virtual training before Urban OpEx conduct and one hour of in-person training, which also may have impacted how the evaluators interacted with the technology.

1.5 PRODUCT DESCRIPTION

CENTAUR by TDCOMM (Figure 1) is a rapidly deployable NIB cellular network platform designed to support first responders and emergency response personnel in deploying a mobile LTE network.

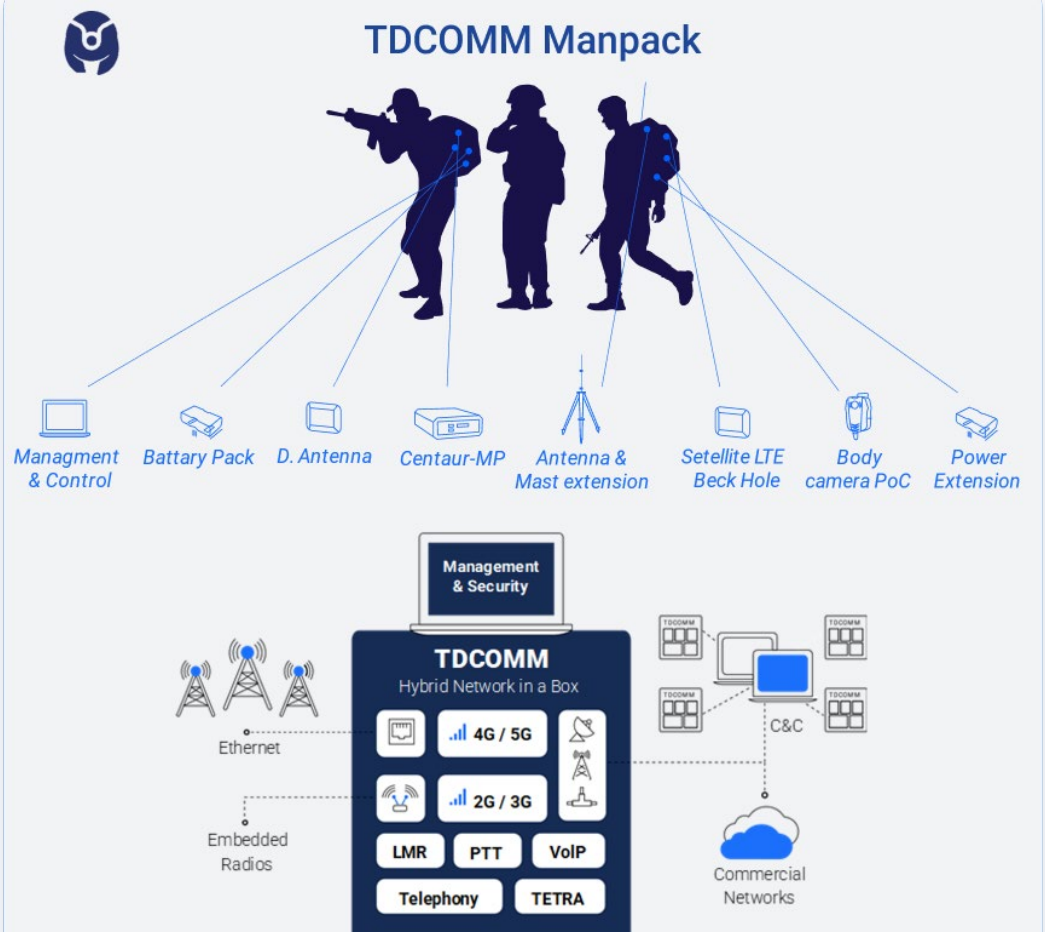

Figure 1: TDCOMM NIB, Manpack, and System Components
Image credit: TDCOMM

The CENTAUR NIB components include:

- Network nodes
- MANPACK node (a lightweight, moveable, and man-packable network node that can be carried by a single person and remains operational on the move)
- Web Client Interface
- Application Server

The CENTAUR Network system requires setting up the NIB and deploying a partial mesh topology, wherein nodes are directly connected within a geographic area (Figure 2). Once the hardware is in place, the authorized user – such as the incident commander (IC) or communications technician – uses the web client interface to determine which communications devices (e.g., radio, mobile phone, computer) to permit to connect to the newly established network. This ensures a secure network with only authorized user access. An IC or admin user can also establish permissions based on the device or role-specific to network slices[2] or network bands.[3]

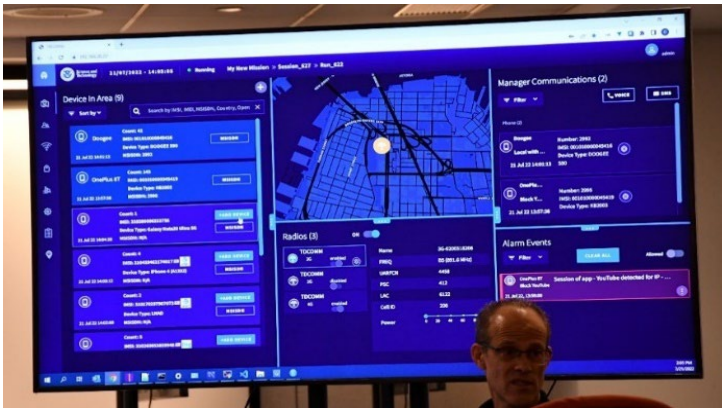

Figure 2: CENTAUR NIB Dashboard

TDCOMM designed CENTAUR to support multiple user groups, including first responders with dedicated mobile devices or subscriber identify module (SIM) cards and ad hoc users and guests using public network devices and SIM cards. CENTAUR enables dedicated channels and controls for each group to ensure resource priorities and the security of each user group. Embedding a radio over internet protocol (RoIP) gateway, the TDCOMM NIB acts as a network interconnection gateway between technologies and organizations (Figure 3).

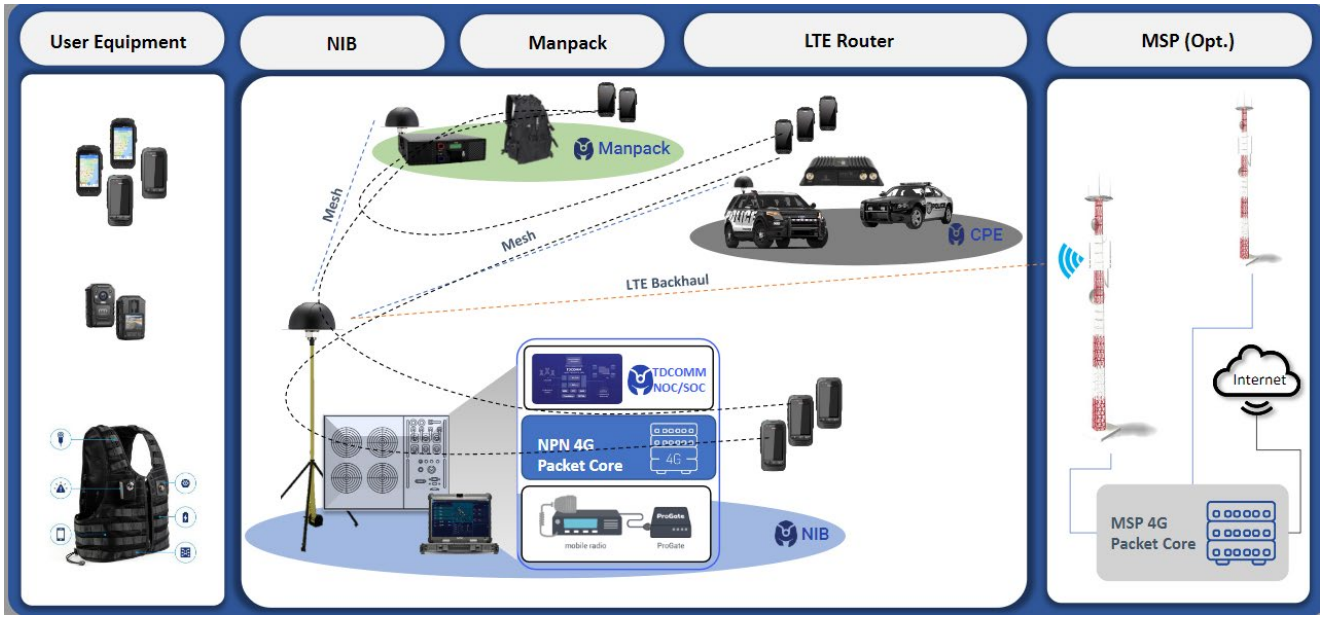

Figure 3: Diagram of TDCOMM CENTAUR Network
Image credit: TDCOMM

[2] Network slicing overlays multiple virtual networks on top of a shared network. Each slice of the network can have its own logical topology, security rules, and performance characteristics within the limits imposed by the underlying physical networks. www.techtarget.com/whatis/definition/network-slicing.
[3] A network band is a range or set of frequencies used by a network to communicate data.

2.0 EXPERIMENT DESIGN

Input from first responders, emergency response personnel, the technology developer, the OpEx Program, and NUSTL's Urban OpEx Experimentation Director helped develop the operational scenario to test CENTAUR's mesh connections, communication clarity, and data feeds (Figure 4). The scenario was designed to allow first responders flexibility to experiment with features most relevant to their unique missions. By enlisting first responders in the scenario development process, the Urban OpEx Planning Team ensured that the scenario would use the technology in activities that were as operationally accurate and relevant as possible.

Figure 4: Evaluators Using CENTAUR during Urban OpEx Experiment

Scenario:

- After a natural disaster, regional and first responder, and emergency response personnel communications have been adversely impacted

Critical tasks for the experimentation included:

- Setting up the NIB
- Connecting mobile devices to the network
- Moving about and testing connections
- Evaluating signal strength and voice quality
  - Collecting and visualizing mobile user identities within the defined area
  - Performing cross-technology communications for first responders over voice, messaging, and video
  - Utilizing Push-To-Talk (PTT) in smartphones and across Motorola Land Mobile Radio (LMR)
- Controlling services, applications, and bandwidth within user groups to ensure priority of service and security of communications

After the experiment, evaluators were asked to consider how this technology would affect their current standard operating procedures and whether CENTAUR could be used to augment their response capabilities.

2.1 SUMMARY OF THE OPERATIONAL EXPERIMENT

NYCEM and FRRG representatives convened at NYCEM Headquarters in Brooklyn, New York, to participate in the CENTAUR evaluation. 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.

Seven first responder evaluators experimented with CENTAUR; their agency affiliations are shown in Table 2. Each evaluator was paired with at least one data collector who recorded their observations of the experiment along with real-time feedback from the evaluator. Table 3 summarizes the equipment used for this experiment.

Figure 5: Evaluators Learning About CENTAUR

Table 2: Evaluators for CENTAUR

Agency	Number
Lubbock (TX) Fire Rescue	1
North Carolina Department of Information Technology	1
NYCEM	3
Oswego (NY) Fire Department	1
San Diego (CA) Fire-Rescue Department	1

Table 3: Equipment Used During Experimentation

Equipment	Description
TDCOMM Devices	NIB components
Radios	Motorola LMRs for first responder evaluators to use for experimentation
Two Antennas	Omni Antennas (low gain and higher gain)
TV Monitor	NYCEM in-house screen displays
Vehicle	Large truck used to power TDCOMM devices
Lenovo Laptop	Laptop for first responder evaluators and technology providers to use for experimentation
Mobile Phones	TDCOMM provided two mobile phones for testing

2.1.1 CONDUCTING EXPERIMENTATION ACTIVITIES

Activities began with a classroom presentation from the OpEx Program, NUSTL, and NYCEM that provided an overview of Urban OpEx and its purpose. The Experimentation Director then provided additional opening remarks and a safety briefing. Next, TDCOMM technology developers then presented an overview of the CENTAUR network and trained evaluators on the operation and capabilities of CENTAUR. After approximately 30 minutes of hands-on training, evaluators began the test activities by operating CENTAUR outside of NYCEM Headquarters.

Figure 6: CENTAUR Network

The Urban OpEx Planning Team devised two test activities: one set focused on using CENTAUR to conduct network stability and the other on communications prioritization. These activities tested CENTAUR's capabilities to execute various functions first responders may require during an emergency response (Figure 6). The Experimentation Director and OpEx staff compressed the network stability and communications prioritization activities into one vignette to provide additional time for evaluator use of the system.

As part of the network stability activities, two evaluators set up the NIB in a park directly across from NYCEM Headquarters. They then set up mesh connections between nodes, Motorola LMRs, legacy LMRs (e.g., P25, TETRA), RoIP, and mobile phones, and scanned for connected devices. During the experiment, evaluators, with help from TDCOMM technology developers, scanned the network to seek the proper spectrum and band for operation, manually demonstrating the system's radio frequency (RF) optimization capabilities. Evaluators took turns using two TDCOMM-provided mobile devices and moved various distances from each other to test the range of the network. Communication among a larger number of mobile users was not included as part of the experimentation scenario. At the same time, those evaluators inside staffing a mock IC evaluated signal strength and voice quality.

2.2 DATA COLLECTION

The Urban OpEx Planning Team assigned data collectors to observe first responder evaluators and collect their feedback during the experimentation. Throughout the experiment, the Urban OpEx Planning Team encouraged evaluators to voice their opinions to assigned data collectors. The Urban OpEx Planning Team obtained feedback from the evaluators in several ways:

- During the experimentation, at least one data collector worked with each evaluator to capture their comments, concerns, and difficulties
- After the experimentation, evaluators completed a questionnaire that recorded their opinions on the functionality of CENTAUR for first responders and emergency response personnel
- Finally, the Experimentation Director led a technology debriefing where evaluators provided additional comments and feedback that note takers collected and consolidated. 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 of Urban OpEx 2022 contain three types of feedback collection: questionnaire feedback, data collector notes, and notes taken during the technology debriefing. These results will help first responder agencies understand whether CENTAUR may be appropriate for their operations and will provide information to TDCOMM on the strengths and opportunities for improvement of their technology.

Each of the evaluators come from different regions, disciplines, and levels of experience, this diversity of experience yielded user feedback that at times may appear contradictory. However, most evaluators were in agreement with each other unless otherwise noted.

3.1 QUESTIONNAIRE FEEDBACK

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

Evaluators mostly agreed that CENTAUR performed all capabilities outlined by the vendor and that it could be used to help fulfill their agency's mission. Only three out of seven evaluators, however, indicated that CENTAUR was an improvement over the technology they currently use. Four of seven evaluators agreed that the user interface was intuitive and easy to engage with and understand. All but one evaluator indicated that CENTAUR would improve their ability to communicate during a multiagency response, to share information, and to coordinate with other agencies or groups because it establishes communication networks when they are otherwise unavailable (Figure 7).

Figure 7: Evaluators Setting Up CENTAUR

Table 4: Evaluators' Responses to 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	2	0	3	2	0
This technology is an improvement on the technology urban first responders currently use.	0	1	2	2	1	1
This technology performed all capabilities outlined by vendor	0	1	0	4	1	1
Responders are able to easily use this technology in conjunction with their required personal protective gear, if applicable to the scenario.	0	1	2	3	0	1
The computer/mobile device user interface was intuitive and easy to both understand and engage with.	1	2	0	3	1	0
The technology was easy to use with little to no interference from vendor during testing.	1	3	1	1	1	0
This technology increases urban first responders' ability to communicate and disseminate information during an event or incident.	0	1	0	4	2	0
This technology can improve first responders' ability to communicate and coordinate with other agencies and groups.	0	1	0	3	3	0
This technology can improve my ability to review and report information back to my leadership.	0	1	0	4	2	0
This technology should be recommended to other urban first responders.	0	2	1	1	1	2

Part two of the questionnaire asked evaluators open-ended questions to describe what features they found most and least useful. Evaluators expanded upon these answers by describing potential solutions to troubleshoot the issues they faced when operating CENTAUR.

Most evaluators did not believe CENTAUR could be an asset to their organization. Many indicated that the range of use cases was narrow and that they would need to see it perform in additional circumstances such as testing communications at longer ranges or testing the systems with significantly more devices to determine its overall utility. Unfortunately, legal and regulatory restrictions may impede evaluating some of these use cases and features in the United States.

During operational activities, data collectors recorded evaluators' comments about positive attributes and challenges they experienced while operating CENTAUR. Data collectors recorded evaluator feedback on technical issues, capability limitations due to Federal Communications Commission (FCC) regulations, and usability challenges with ease of setup, operation, and user interface. After the experiment, the Experimentation Director led a debriefing to solicit further evaluator feedback. Table 5 summarizes the evaluator feedback captured during test activities and the debriefing and is organized into categories: Physical Configuration, Deployment and Setup, and Communication Network Ability.

Table 5: Evaluators' Responses to Questions on CENTAUR's Features

Application	Most Useful Features	Least Useful Features/Problems	Changes and Recommendations
Physical Configuration	▪ MANPACK node is lightweight and easy to deploy and transport (although the MANPACK was not evaluated) ▪ Recording feature must be manually activated by the laptop user rather than the system automatically recording	▪ Software interface display on laptop is difficult to navigate and overly complicated (e.g., one evaluator had to click through four screens to get to a call)	▪ Vendor should tailor the demonstration to specific agencies' needs ▪ Add a label or icon on the outside of the backpack to show on which side the batteries should be inserted ▪ Add a line or arrow to ease orienting and aligning the cables to the connectors on the backpack ▪ In the software, make the tab for accepting a phone larger ▪ Add shortcuts or other ways to simplify navigation through different panes and windows) to the graphical user interface (GUI) ▪ Add simple improvements to the GUI such as adding a "select all" button to select/de-select multiple options simultaneously (e.g., countries)
Deployment and Setup	▪ Easily deployable ▪ Scans for devices and networks immediately following setup	▪ Complex network setup required significant vendor assistance ▪ Configuring and running the system requires a dedicated communications technician (One evaluator said that each organization would need its own subject matter expert to use this technology) ▪ Narrow set of technology applications (i.e., situations with downed cell service) ▪ Audio recordings are not a useful feature to some responder's mission sets ▪ Currently not licensed by the FCC	▪ Define real-world use cases where this technology can better support first responders ▪ Make system easier to use out of the box, without compromising functionality ▪ Create easier "record" feature ▪ Create a single layer for all functions (i.e., user should not need to press multiple buttons to use SMS, voice, and data)

Application	Most Useful Features	Least Useful Features/Problems	Changes and Recommendations
Communication Network Ability	▪ Connects to mobile phones ▪ Phone-to-radio capability operates smoothly within a short range ▪ Integrates with the server "over-the-top" (i.e., provides service on top of existing network infrastructure, enabling operation if networks are down) ▪ Supports a variety of spectrums and bands: all LTE, frequency division duplex (FDD) bands, time division duplex (TDD) bands) ▪ Meshes well with different devices	▪ Modem was unable to connect to evaluators' personal devices and could only connect to vendor-provided devices ▪ Unable to make calls to devices outside of the CENTAUR network ▪ Call recording capability is not intuitive (required significant vendor involvement) ▪ Evaluators could not experiment with a network range larger than 100–200 feet. (This network range was shorter than the parameter set by the OpEx planning team) for that capability) ▪ Carrier-locked cell phones (a device usable only on that carrier's network) could be prevented from joining NIB networks in an emergency. ▪ Adding mobile devices to the network raises privacy violation concerns	▪ Add ability to define internal and external user groups so that an agency could give internal users access to make voice calls, SMS, and data. (External users should only have access to one or two of those options to prioritize responder access on network.)

4.0 CONCLUSION

Evaluators' feedback on CENTAUR was mixed. Throughout the debrief session and questionnaire written responses, evaluators reiterated that the technology's ability to operate in austere environments and to transmit data clearly are positive attributes that would make them more likely to use it. They reported the devices were easy to connect to the network, which worked well within the ranges this assessment evaluated. Evaluators also found the ability to integrate many different devices into this network, should other networks fail, as a beneficial capability. This feature is significant because it helps keep personnel safe and connected during emergencies. CENTAUR's wide selection of compatible spectrums and bands makes it flexible across different mission areas.

A majority of evaluators noted several shortcomings while testing CENTAUR. For example, the network setup at the mobile command center proved extremely difficult and required significant hands-on support from TDCOMM representatives. Evaluators also noted that the demonstrated configuration's call recording capability was not intuitive. Additionally, several evaluators noted that carrier-locked cellular devices might be restricted from joining the NIB during an emergency, hindering CENTAUR's utility in ad hoc cellular service use cases.

Participants offered solutions to address these problems, including:

- Categorize internal and external users to limit external user access to internal metrics
- Simplify the network setup and connection processes through additions to the GUI, such as arrows, labels, and icons
- Create a more intuitive and user-friendly product interface (e.g., adding a "select all" button)

Urban OpEx 2022 experimentations were conducted in a half-day timeframe. They were driven by a tailored set of scenarios that limited the evaluator's exposure to a typical training program, broader technology configurations outside the planned scenario, and additional features/configurations of the technology not applicable to the scenario. Given these constraints, it is possible that some first responder evaluator feedback or suggestions for improvement could be addressed with the completion of the entire technology provider-recommended training program.

In conclusion, the majority of evaluators found that CENTAUR would have limited utility for most agencies. Most evaluators agreed that CENTAUR performed all capabilities outlined by the vendor and that it could be used to help their agency's mission. Some evaluators worried that CENTAUR's capabilities might invoke additional regulatory compliance hurdles or constraints. Many evaluators noted that the system is complicated and that configuring and running the system would require skilled personnel. The costs, in both money and time, of owning, maintaining, and using the system, outweigh the benefits to first responder agencies. The feedback from evaluators may enable the technology vendor to improve the product and expand the number of use cases where CENTAUR could support first responders' work.

5.0 ACRONYM LIST

Acronym	Definition
CRADA	Cooperative Research and Development Agreement
DHS	Department of Homeland Security
DMR	Digital Mobile Radio
ExPlan	Experimentation Plan
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FDNY	New York City Fire Department
FRRG	First Responder Resource Group
GUI	Graphical User Interface
IC	Incident Commander
ID	Identification
LMR	Land Mobile Radio
LTE	Long Term Evolution (e.g., 4G or Fourth Generation)
MTA	Metropolitan Transportation Authority
NIB	Network in a Box
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
PTT	Push to Talk
RF	Radio Frequency
RFI	Request for Information
RoIP	Radio over Internet Protocol
S&T	Science and Technology Directorate
SIM	Subscriber Identity Module
SME	Subject Matter Expert
TDD	Time Division Duplex
UAS	Unmanned Aircraft Systems