Portable Radio Repeaters for Indoor and Subterranean Environments

Assessment Report

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TECHNOLOGY LABORATORY

SAVER-T-R-28

FOREWORD

The National Urban Security Technology Laboratory (NUSTL) is a federal laboratory within the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T). Located in New York City, NUSTL is the only national laboratory focused exclusively on supporting the capabilities of federal, state, local, tribal, and territorial responders to address the homeland security mission. The laboratory assists responders with the use of technology to prevent, protect against, mitigate, respond to, and recover from homeland security threats and incidents. NUSTL provides expertise on a wide range of subject areas, including chemical, biological, radiological, nuclear, and explosive detection, personal protective equipment, and tools for emergency response and recovery.

NUSTL manages the System Assessment and Validation for Emergency Responders (SAVER) program, which provides information on commercially available equipment to assist response organizations in equipment selection and procurement. SAVER knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" The SAVER program works with responders to conduct objective, practitioner-relevant, operationally-oriented assessments and validations of commercially available emergency response equipment. Having the right tools provides a safer work environment for responders and a safer community for those they serve.

NUSTL is responsible for all SAVER activities, including selecting and prioritizing program topics, developing SAVER knowledge products, and coordinating with other organizations to leverage appropriate subject matter expertise. Under the SAVER Program, NUSTL — in conjunction with U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) — developed this report to provide emergency responders with information obtained from a comparative assessment of portable radio repeaters for indoor and subterranean environments, which fall under the AEL reference number 06CP-01-REPT titled "Repeaters."

For more information on NUSTL's SAVER Program and portable radio repeaters for indoor and subterranean environments or to view additional reports on other technologies, visit: www.dhs.gov/science-and-technology/SAVER.

SAVER reports are available at www.dhs.gov/science-and-technology/saver-documents-library.

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

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EXECUTIVE SUMMARY

A radio repeater is a device that receives a radio frequency (RF) signal and re-transmits it at a higher power level to extend the effective coverage range. First responders deploy portable radio repeaters in areas with degraded radio coverage (e.g., indoors, underground, or rural areas) to extend the coverage range of their radios.

From September 21-24 of 2021, the National Urban Security Technology Laboratory's (NUSTL's) System Assessment and Validation for Emergency Responders (SAVER) program conducted an assessment of portable radio repeaters for indoor and subterranean environments at the Philadelphia Emergency Operations Center (EOC) in the Philadelphia Fire Department's (PFD) Fire Administrative Building (FAB). The Department of Energy (DOE) Pacific Northwest National Laboratory (PNNL) supported planning, execution, and documentation of the assessment.

During the assessment, eight emergency responder evaluators worked in teams of two and rated four portable radio repeaters based on a set of 18 evaluation criteria established by a focus group of emergency responders in October 2020. The assessment was conducted in two phases: the specification assessment and the operational assessment. Evaluators assessed the products based on vendor-provided information during the specification assessment. The evaluators' hands-on experience using the products in five scenarios served as the basis for the operational assessment. They configured each repeater, hand carried it to an activity site at the assessment venue, activated the repeater and then communicated with each other on push-to-talk (PTT) radios while adjusting parameters on the repeater. Evaluators also participated in a simulated urban search-and-rescue exercise as the final operational assessment scenario. The table below presents the overall scores as well as the category scores for each of three portable radio repeaters.

The fourth product, BK Technologies Rapid Deployable Portable Repeater (RDPR), was included in the assessment, but evaluators did not consider the product a "true repeater." The reason behind this distinction is that the RDPR relies on user-supplied components rather than built-in electronics. As such and in accordance with the priority that SAVER places on first responders as the sources of criteria and the evaluators of technologies, all results for the RDPR are listed in the appendix rather than incorporated into the main body of this report.
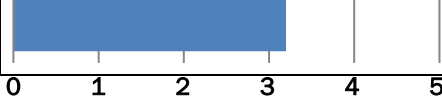
Product	Overall Score	Overall	Capability	Usability	Deployability	Maintainability
Etherstack SFFR-6 "GoBox"		4.1	4.0	4.5	4.0	4.0
Codan Stratus Transportable Repeater		3.8	3.7	3.6	3.9	4.1
Motorola/Futurecom PDR8000		3.2	3.2	3.3	3.6	2.3

Key: 1 (least favorable) to 5 (most favorable)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Radio communications are essential to emergency response operations. Communications in indoor and underground areas are often degraded due to poor radio signal coverage and obstructions to line of sight between two radios. One solution to this problem is using a portable radio repeater. A radio repeater is a device that receives a radio's signal and retransmits it to increase its effective range. A repeater may change the power level, frequency or direction of the retransmitted signal. Portable radio repeaters can be deployed in indoor and subterranean environments as needed to increase radio coverage and enhance effective communications in emergency response operations.

In September of 2021, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an assessment of portable radio repeaters for indoor and subterranean environments at the Philadelphia Office of Emergency Management's Emergency Operations Center (EOC) in the Philadelphia Fire Department's Fire Administration Building (FAB). The purpose of the assessment was to obtain information on portable radio repeaters to assist with operational and procurement decisions. The assessment activities were based on recommendations gathered from a focus group (conducted in October 2020) of emergency responders with experience using portable radio repeaters [1] and developed in an assessment plan [2] completed prior to the assessment.

1.1 Participant Information

Eight emergency responders assessed the portable radio repeaters following procedures developed by the National Urban Security Technology Laboratory (NUSTL) and the Pacific Northwest National Laboratory (PNNL). Evaluators were selected for the assessment based on their respective emergency response discipline, geographic location and professional experience using portable radio repeaters. Due to travel restrictions associated with the COVID-19 pandemic, evaluators were only recruited from the states of Pennsylvania, New Jersey and New York. Evaluators' professional information is listed in Table 1-1.

Table 1-1 Evaluators' Professional Backgrounds

Evaluator Discipline	Years of Experience	State
Emergency Communications Manager	11-15	PA
Emergency Management	0-5	PA
Firefighting	21-25	PA
Firefighting/Emergency Communications Technician	16-20	PA
Firefighting/HazMat Technician	21-25	NJ
Firefighting	21-25	NY
Law Enforcement	21-25	PA
Law Enforcement/Emergency Communications Technician	30-35	PA

1.2 Assessed Products

Four products were selected and borrowed from vendors for the assessment based on market research and recommendations from the focus group:

- BK Technologies Rapid Deployable Portable Repeater (RDPR)

- Codan Communications Stratus Transportable Repeater

- Etherstack SFFR-6 "GoBox"

- Motorola Solutions/Futurecom PDR8000

During the assessment, evaluators recommended separating the BK Technologies RDPR from the other products because they did not see it as a "true repeater." The RDPR is not a standalone repeater but rather relies on user-supplied handheld radios that are plugged into the case, as opposed to built-in electronics, to receive and re-transmit signals. Despite this difference, the product was assessed using the evaluation criteria listed in Section 2.0 and the procedures described in Section 3.0. Assessment results for this product are listed in Appendix B rather than in Section 4.0.

1.3 Selection Criteria

Product selection criteria identified specifications, attributes, or characteristics a product should possess to be considered for the assessment. The assessment team established the following product requirements when determining the scope of product types for the assessment:

- The product is available to emergency responder organizations as a commercial off the shelf (COTS) or government off the shelf (GOTS) product.

- The product is deployable as needed for different indoor and underground emergency response operations (i.e., the product is not a fixed installation solution.) Products that operate exclusively as satellite communications (SatCom) systems were not included in the assessment.

- The product is compatible with P25 radio systems.

- The product is contained within a protective enclosure.

- The product is human-portable, (i.e., the combined weight of the repeater and the enclosures is under 50 pounds [approximately 22.6 kilograms] or the enclosure is equipped with wheels if the combined weight is over 50 pounds). No cell-on-wheels or cell-on-light truck systems were included in the assessment.

Focus group participants suggested considering the following factors [1] when selecting portable radio repeaters for the assessment:

- **Ease of Deploying:** Products included in the assessment should be relatively easy to deploy with only basic emergency response communications training and should not require a trained technician.

- **Power Classes:** Low (0 W–19 W), medium (20 W–49 W), and high (50+ W) power classes were defined during the focus group as a method to categorize portable radio repeaters. Each power class can be used for specific applications. The assessment should either focus specifically on one power class or have representation across all three power classes.

  The products selected for the assessment represent low and medium power classes. No high-power repeaters were chosen as the products considered by the assessment team did not meet the other requirements and recommendations.

- **Operating Modes:** Repeaters should be compatible with both digital and analog systems or have alternate models for each. Repeaters should be compatible with conventional and trunking[1] radio systems.

  While the repeaters selected for this assessment are compatible with both analog and digital radios and some are compatible with both conventional and trunking radios, the products were tested only with digital conventional radios.

- **Network Compatibility:** In addition to land mobile radio (LMR) networks, products included in the assessment should be compatible with a variety of networks, including LTE, 5G, FirstNet and local Wi-Fi.

  While some of the selected repeaters are compatible with multiple networks, assessment products were tested on a land mobile radio network during the assessment. LTE and Wi-Fi networks were not used to demonstrate additional features of the selected repeaters.

- **Software Defined Radio:** Products which have a software defined radio element present more opportunities for repeater configuration and programming.

  None of the products included in the assessment included a software-defined radio element.

- **Remote Controls and Monitoring:** Repeaters may have a feature which allows technicians or other users to remotely monitor repeater status and parameters and adjust the repeater as necessary.

  None of the products included remote controls and monitoring features.

- **Known Vendors:** Focus group members said they would be extremely reluctant to purchase products sold by a manufacturer or distributors about which little information is available.

Based on market research and the focus group's recommendations, the SAVER assessment team considered 25 products from 15 vendors for the assessment. Each product was considered based on how well it met the product selection criteria. The BK Technologies RDPR, Codan Stratus, and Motorola/Futurecom PDR8000 were selected because these three radio repeater models are widely used and were also recommended by the focus group [1]. The Etherstack SFFR-6 GoBox was selected for the assessment for its small footprint, resulting in enhanced portability of the system.

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[1] Users of conventional radio systems must manually tune communications equipment to channels designated in a communications plan. A trunking radio system scans the available spectrum and automatically tunes communications equipment to the first available channel. https://www.taitradioacademy.com/topic/how-does-trunking-work-1/

These products represented low-power and medium-power repeaters and are all capable of supporting analog and digital radio communications. The Codan Stratus is the only product with LTE network compatibility.

The products selected for assessment and their key specifications are shown in Table 1-2.

Table 1-2 Assessed Products' Key Specifications

Product	MSRP	Frequencies	RF Power	Size (L x W x H)	Weight	Additional Features
BK Technologies Rapid Deployment Portable Repeater (RDPR)	$3,800*	VHF† UHF† 700/800 MHz †	†	16.2" x 12.7" x 6.6"	17 lb.‡	Radio-specific interface kits sold separately
Codan Communications Stratus Transportable Repeater	$29,500	VHF: 136-174 MHz UHF: 380-520 MHz 700/800/900: 768-869 MHz 896-960 MHz	30 W (VHF, UHF) 25 W (700/800) 3 W (900)	15.2" x 9.2" x 7.3"	32 lb.	Optional cellular 3G/LTE network interface DFSI§
Etherstack SFFR-6 GoBox	$25,000	VHF: 136-174 MHz UHF: 380-520 MHz	1 W 2 W 5 W 10 W 15 W	8.5" x 10.2" x 7.8"	20 lb.	Duplexer bypass DFSI§
Motorola Solutions PDR8000 Repeater	$16,000	VHF: 136-174 MHz UHF: 380-430 MHz 450-470 MHz 700/800: 764-776 MHz 794-806 MHz 806-824 MHz 851-869 MHz	20W (VHF) 19W (UHF) 16W (700) 17W (800)	19.2" x 15.2" x 7.3"	28 lb.	Optional booster pack (50W across all bands) Optional duplexer Optional cross-band interoperability

Notes: The specifications in this table represent available configurations, rather than the equipment as assessed.
* – indicates price may not reflect total cost of device operation
† – The BK Technologies RDPR does not have a built-in transmitter and receiver and instead relies on handheld donor radios to operate. As such the operating frequencies and power levels are determined by the features of those radios and not the radio repeater device itself.
‡ – The listed weight of the RDPR reflects the product without handheld radios installed. The total weight of the system with handheld radios installed is more than 17 lbs.
§ – DFSI stands for Digital Fixed Station Interface, which provides a vendor-agnostic standard for interoperability with P25 communications equipment.

2.0 ASSESSMENT CRITERIA

The SAVER focus group on portable radio repeaters for indoors and subterranean environments identified 28 assessment criteria, including 9 "information only" criteria, and assigned each criterion to one of the five established SAVER assessment categories [1] defined below:

- **Affordability** criteria relate to the total cost of ownership over the life of the product. This includes purchase price, training costs, warranty costs, recurring costs and maintenance costs.

- **Capability** criteria relate to product features or functions needed to perform responder relevant tasks.

- **Deployability** criteria relate to preparing to use the product, including transport, set up, training and operational/deployment restrictions.

- **Maintainability** criteria relate to the routine maintenance, storage, calibration and minor repairs performed by responders, as well as included warranty terms, duration and coverage.

- **Usability** criteria relate to ergonomics and the relative ease of use when performing responder relevant tasks.

Each "evaluation" criterion was assigned a weight for its level of importance on a scale of 1 to 5, with 1 signifying "somewhat important" and 5 signifying "of utmost importance." Those criteria designated as "information only" were not assigned a weight. Each product's features, specifications and performance related to the "information only" criteria are included in this report but do not contribute to the product's numerical evaluation score. The focus group also ranked the SAVER categories and assigned a percentage to each SAVER category representing its level of importance. Five of the eleven Capability criteria were also designated "information only."

Table 2-1 lists "information only" criteria as well as their associated SAVER categories. As opposed to "evaluation criteria," these criteria are assessed but do not contribute a product's score.

Table 2-1 Information Only Criteria

SAVER Category	Information Only Criteria
Capability	Data and Video
	Intrinsic Safety
	Monitoring and Alerting
	Multi-Band Interoperability
	Operating Mode
Affordability	List Price
	Contract Pricing
	Maintenance Costs
	Warranty

The Affordability category was designated an "information only" category in recognition of the differences in various agencies' and jurisdictions' budgets. Information on product affordability is included in this report but does not contribute to a product's overall score. The Affordability category includes three criteria.

Additionally, while the evaluation criterion "Compatibility with Fixed Infrastructure" was assigned a weight of 5 during the focus group (representing high significance for users making purchasing decisions), this criterion could not be assessed due to the lack of fixed radio repeater infrastructure at the assessment venue. As such, this criterion is not addressed in Section 4.0.

Evaluators assessed 18 of the 19 weighted criteria listed in Table 2-2 as well as the nine criteria designated "information only." Table 2-2 presents the weighted criteria against which repeaters were assessed and their associated weights as well as the percentages assigned to the SAVER categories. Refer to Appendix A for the evaluation criteria definitions.

Table 2-2 Evaluation Criteria

SAVER Categories			
Capability	Usability	Deployability	Maintainability
Overall Weight 40%	Overall Weight 25%	Overall Weight 20%	Overall Weight 15%
Evaluation Criterion			
Encryption Weight: 5	Audio/Voice Clarity Weight: 5	Ease of Setup Upon Arrival Weight: 5	Component Replaceability Weight: 5
Antenna Options Weight: 4	Compatibility with Fixed Infrastructure Weight: Not Assessed	Ease of Configuration Weight: 4	Durability Weight: 5
Battery Capacity Weight: 4	Ease of Use in Field Weight: 5	Internal Storage Space Weight: 4	In-House Maintenance Weight: 4
Channel Capacity Weight: 4	Channel Selection Weight: 4	Physical Weight Weight: 4	Maintenance Frequency Weight: 3
Power Level/Range Weight: 4		Size Weight: 4	
Power Source Options Weight: 4			

3.0 ASSESSMENT METHODOLOGY

The assessment took place September 21 through 24, 2021 at the Philadelphia Office of Emergency Management's EOC in the Philadelphia Fire Department's FAB. On the first day, assessment team members from NUSTL provided a safety briefing and an overview of the assessment process, procedures and schedule to the evaluators. Evaluators then assessed each product in two phases: (1) specification assessment and (2) operational assessment.

Throughout the majority of the assessment, evaluators worked in teams of two. A NUSTL data collector observed and documented the findings of each team of evaluators as they completed the assessment activities. All evaluators participated in the simulated urban search and rescue exercise (see Section 3.2.5) simultaneously. At the end of the assessment, data collectors shared the overall results with evaluators and evaluators were given the opportunity to adjust their scores as necessary. In general, evaluators noted that the repeaters were easy to transport, easy to deploy on scene, and provided sufficient signal quality for operational use when equipped with proper antennas.

3.1 Phase 1: Product Familiarization and Specification Assessment

At the start of each product assessment, vendor representatives, serving as product subject matter experts, provided a short product familiarization presentation to evaluators in the EOC. This session covered features, specifications and basic repeater operations. Assessment team members from NUSTL and PNNL assisted evaluators with product familiarization and evaluators had access to reference material that comes standard with purchase of each product.

Items covered during the presentation included the following:

- RF specifications, including transmission frequencies, channel bandwidth, transmission power, receiver sensitivity and encryption methods
- Peripheral components, including antennas and power sources
- Physical specifications, including size, weight and durability features
- Maintenance information
- List price and associated costs
- How to configure, deploy and use the repeater
- Additional features, such as data and video capability or monitoring tools

Criteria assessed during this phase are listed in Table 3-1.

Table 3-1 Criteria Assessed During Phase 1

Evaluation Criteria		Information Only Criteria	
・Encryption ・Antenna Options ・Battery Capacity ・Channel Capacity ・Power Level/Range ・Power Source Options ・Channel Selection	・Internal Storage Space ・Physical Weight ・Size ・Component Replaceability ・Durability ・In-House Maintenance ・Maintenance Frequency	・Data and Video ・Intrinsic Safety ・Monitoring and Alerting ・Multi-Band Interoperability ・Operating Mode	・List Price ・Contract Pricing ・Maintenance Costs ・Warranty

Figure 3-1 Repeaters Test Activities

Clockwise from top left: Vendor representative providing product overview to evaluators and data collector; evaluators configuring repeater for deployment; evaluators deploying repeater; incident commander and data collectors during USAR scenario; evaluator communicating with outdoor evaluators and data collector observing; evaluator selecting antenna position during repeater deployment.

3.2 Phase 2: Operational Assessment

During the operational assessment, evaluators assessed each product based on their hands-on experience using the portable radio repeaters after having become familiar with their proper use, capabilities and features.

Evaluators gained experience and scored the products in five scenarios:

1. Repeater Configuration and Deployment
2. Benchmark
3. Repeater Activation and Usage
4. Field Reconfiguration
5. Simulated Urban Search and Rescue Exercise

Evaluators used the products, one at a time, and completed the assessment questionnaires for the first four scenarios for each product before assessing the next product. After completing the first four scenarios for each product, all evaluators participated in the fifth scenario at the same time, assessing all products at the same time.

3.2.1 Scenario 1: Repeater Configuration and Deployment

During this scenario, evaluator teams configured their repeater in advance of deployment. This included programming or selecting repeater parameters, such as RF channel and transmission power level, and selecting the appropriate antennas and power sources. The repeater was packed for transport and deployed to one of four activity stations (one for each product) in the basement of the FAB (see Figure 3-2). Details on product configurations that were used during the assessment are included in Sections 4.1 through 4.3 and in Appendix B.

Following a vendor-led product familiarization session, the evaluators moved the repeater to a designated testing location and configured the repeater for operation. However, the repeater was not activated at this point.

Criteria assessed during this scenario are listed in Table 3-2.

Table 3-2 Criteria Assessed During Operational Scenario 1

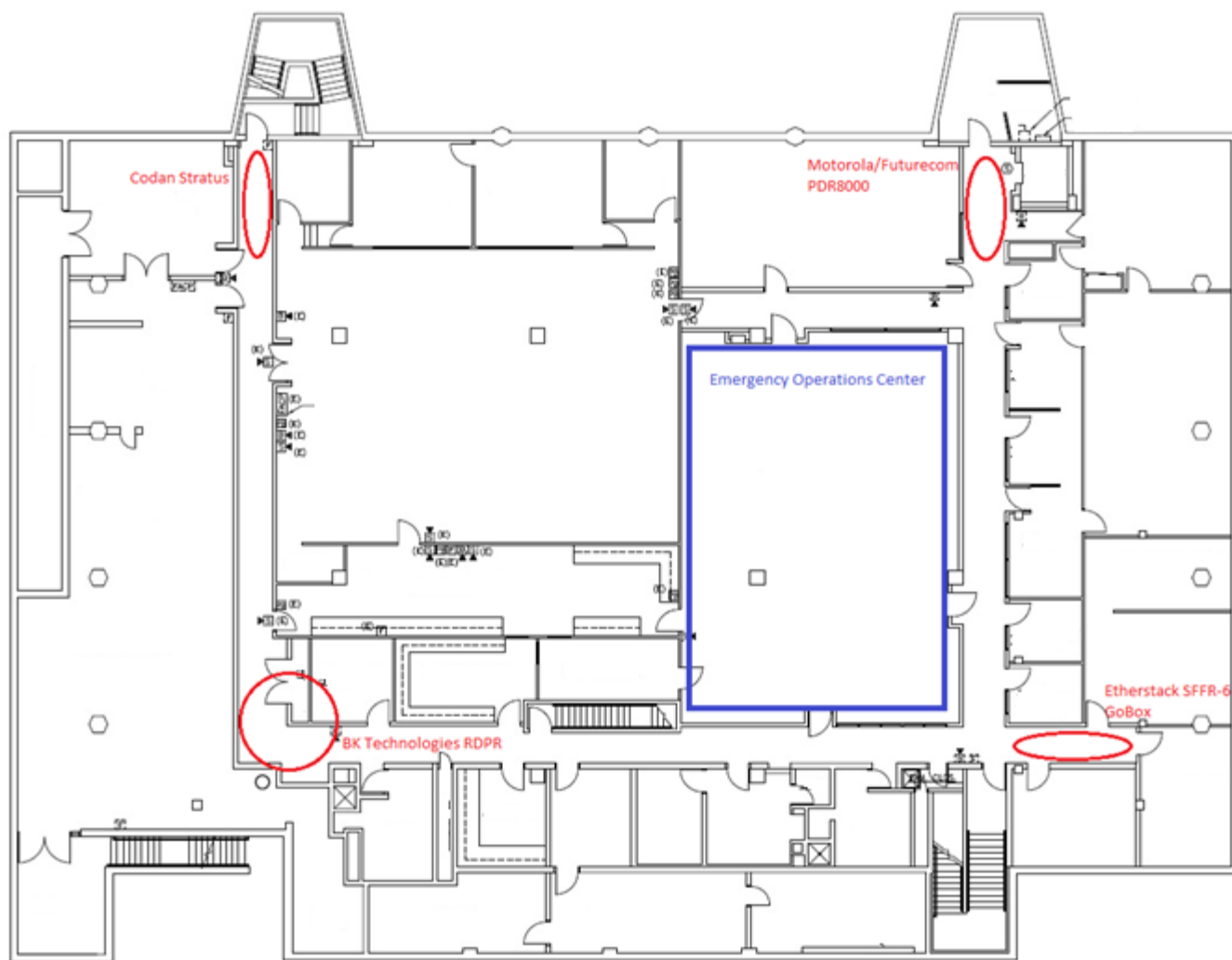| Evaluation Criteria |
| --- |
| Antenna Options |
| Power Source Options |
| Channel Selection |
| Ease of Setup Upon Arrival |
| Ease of Configuration |
| Internal Storage Space |
| Physical Weight |
| Size |
| Durability |

Figure 3-2 Basement Floor Plan of FAB

The blue rectangle indicates the EOC where briefings were conducted. The red circles and ovals indicate the activity station at which each product was placed during the assessment.

3.2.2 Scenario 2: Benchmark

After deploying the repeater and prior to activating it, evaluators conducted a benchmark exercise to observe how the presence of each repeater improves radio communications in indoor and subterranean environments. While conducting the benchmark exercise, one evaluator on the team (designated Evaluator A) remained at the activity station in the basement of the FAB (see Figure 3-2) while the other evaluator (Evaluator B) proceeded to an outdoor location in a parking lot across the street from the FAB (see Figure 3-3 and Figure 3-4).

For the benchmark, Evaluator B walked with handheld radios from the entrance of the FAB towards 4th Street, stopping at each weight-point marked in Figure 3-3. At each location, both evaluators conducted a communications check and performed a mean opinion score (MOS) test [2]. An MOS test is a simplified subjective method of assessing speech intelligibility and audio signal quality. After receiving or hearing a signal, the person on the receiving end scores the intelligibility of the signal on a pre-determined scale. The MOS test conducted during this assessment used the following scale of 1 to 5:

1) Unintelligible (nothing heard)

2) Barely intelligible (some words were overheard but not the entire sentence)

3) Weakly intelligible (the entire sentence was overheard but very faintly)

4) Intelligible (the entire sentence was overheard with little to no problems)

5) Loud and clear (the entire sentence was overheard loud and clear)

Evaluator B stopped at the maximum range, which was defined as the location at which the MOS test resulted in a score of 2.

After determining the maximum range, the evaluators would then conduct an "oily rag" test at the maximum range and at position C in Figure 3-3. Evaluator A would read a seven-word nonsensical sentence off a script prepared by the assessment team. These sentences were selected from an IEEE study on speech quality measurements [2]. The sentences were designed to be phonetically balanced meaning that the sounds spoken occur at approximately the same frequency at which they occur in conversational English. The sentences were also selected to be phonetically balanced. The outside evaluator (Evaluator B) would then repeat the phrase back over radio and the inside evaluator (Evaluator A) would count the number of words that were repeated correctly. Evaluators conducted two "oily rag" tests, using a different sentence for each test, at each location.

3.2.3 Repeater Activation and Usage

After conducting the benchmark exercise, the evaluator positioned at the repeater activated the repeater. The evaluator team then repeated the test procedures described in the previous section, observing how the repeater affected maximum coverage range and received signal quality on both ends. The evaluator with the repeater also observed integrated monitoring features, such as LED indicators or LCD displays, while communicating through the repeater.

Table 3-3 Criteria Assessed During Operational Scenario 3

Evaluation Criteria	Information Only Criteria
・ Power Level/Range ・ Audio/Voice Clarity ・ Ease of Setup upon Arrival	・ Monitoring ・ Alerting

Criteria assessed during this scenario are listed in Table 3-3.
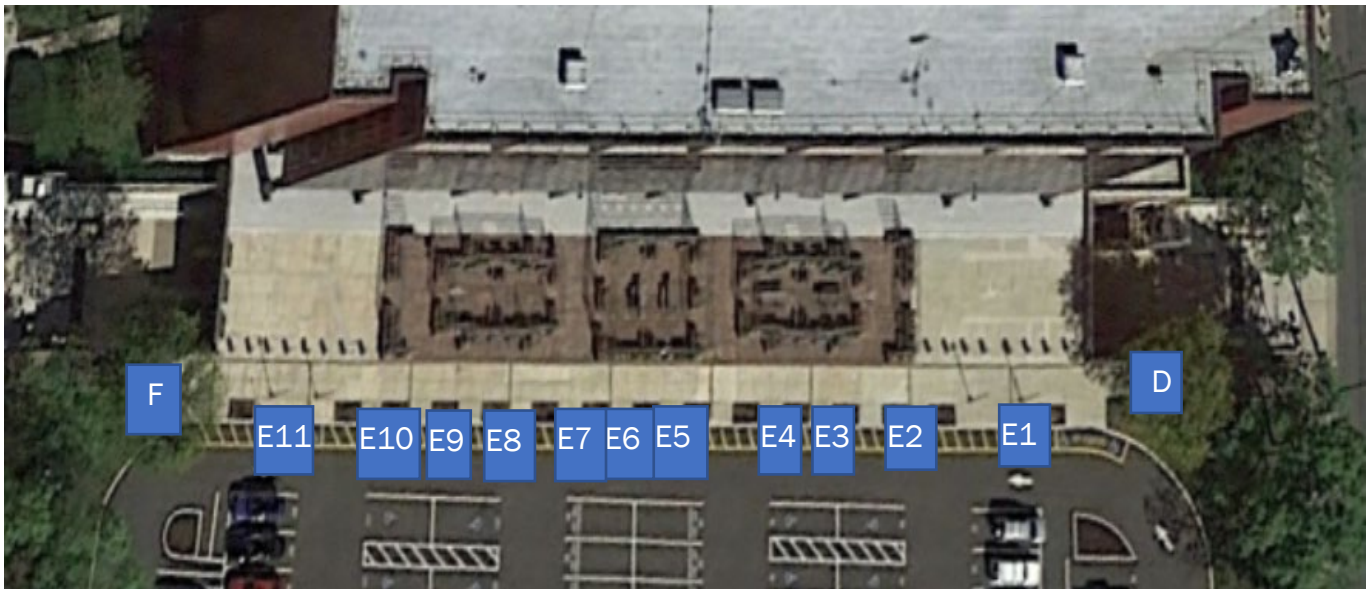
Figure 3-3 Aerial View of Outdoor Test Sites

Top: FAB (A, B), 3rd Street (C), parking (D, E, F), and 4th Street (G, H). Bottom: Detailed view of parking lot.
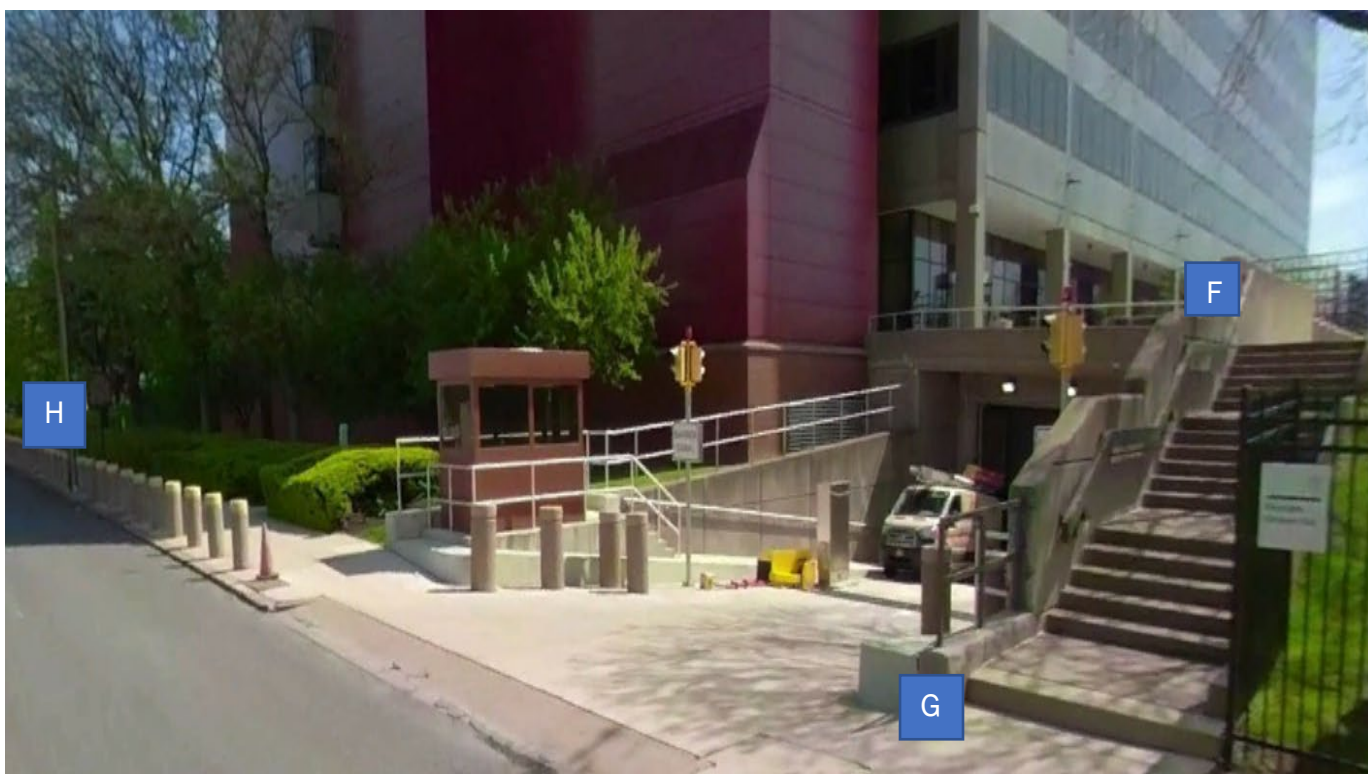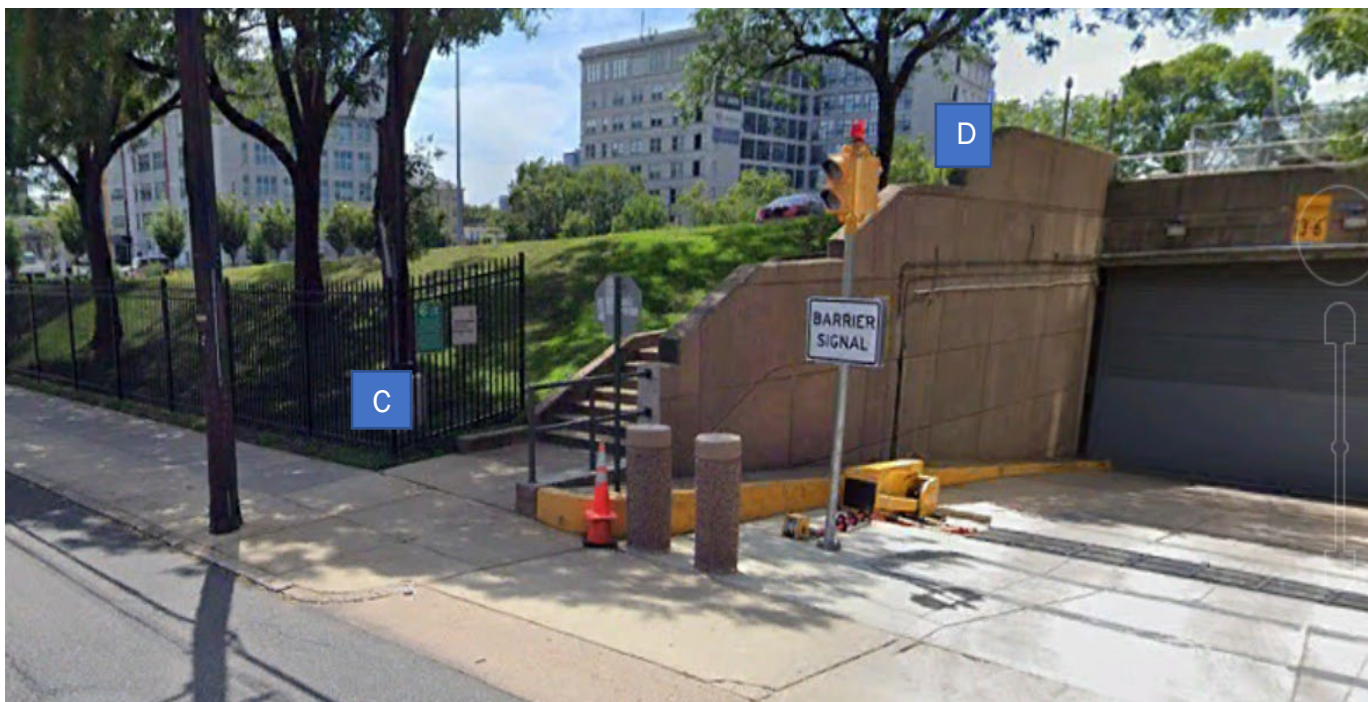
Figure 3-4 Street View of Outdoor Test Sites

Top: View from 3rd Street; Bottom: View from 4th Street.

3.2.4 Field Reconfiguration

During this scenario, an evaluator would adjust one parameter of the repeater's settings and then both evaluators would reiterate the test procedures described in Section 3.2.2. In addition to observing how different configurations affect maximum coverage range and received signal quality, evaluators also observed how quickly the repeater adapted to the new settings. Evaluators conducted at least one field reconfiguration for each product. Reconfigurations that were done during the assessment included the following:

- **Antenna type**: Evaluators replaced the antenna with a different type of antenna.

- **Antenna position:** Evaluators repositioned the antenna on the repeater.

- **Transmission power:** Evaluators adjusted the transmission power level.

- **RF channel:** Evaluators switched the repeater and their handheld radios to a secondary channel.

- **Power source:** Evaluators switched the power source of the repeater.

- **Repeater position:** Evaluators moved the repeater to a different position at the test site.

The results section (Section 4.0) includes configurations assessed for each repeater. It should be noted that due to differences in specifications, different radio models, frequency bands and transmission power levels were used for different repeaters.

Once this scenario was completed, evaluators repacked the repeater for transport, return it to the EOC and scored the product on a scale of 1 to 5. This scale is described in detail in in Section 3.3.

Criteria assessed during this scenario are listed in Table 3-4.

Table 3-4 Criteria Assessed During Operational Scenario 4

Evaluation Criteria		Information Only Criteria
・Antenna Options ・Battery Capacity ・Power Level/Range ・Power Source Options	・Audio/Voice Clarity ・Ease of Use in Field ・Channel Selection ・Durability	・Monitoring and Alerting

3.2.5 Simulated Urban Search and Rescue (USAR) Exercise

After each evaluator team completed the above scenarios for each repeater, all evaluators participated in a simulated urban search and rescue exercise. One evaluator listed in Table 1-1Table 1-1 did not participate in this exercise. Unlike in previous test scenarios, all evaluators participated at the same time in the simulated USAR exercise. This was done to observe how the repeater performed with several users on the same channel. During this exercise, two evaluators served as incident commanders, one evaluator served as a radio technician, and four evaluators served as the rescue team.

Evaluators started the exercise by selecting an ideal deployment position for the repeaters on the first floor of the FAB and then deploying all repeaters to that position. Repeaters were deployed to a hallway on the western side of the building (see Figure 3-5).

Following deployment of the repeaters, evaluators proceeded to their staging areas. The incident commanders were stationed in the garage of the FAB and in the parking lot across the street from the FAB. The radio technician was stationed with the repeaters. The rescue teams were stationed in the basement of the FAB at the start of the exercise and then moved to the stairwells between the first and second floor during the second half of the exercise (see Figure 3-6).

Throughout the exercise, the incident commanders communicated with the radio technician and rescue team over radio, conducting regular communications checks, verifying rescue team location, and providing search pattern instructions.

All evaluators communicated on the same RF channel simultaneously throughout this exercise and cycled through all repeaters. Evaluators observed the received signal quality and coverage range of communications both with and without the use of radio repeaters. Evaluators conducted MOS tests, but not oily rag tests, during this scenario.

Criteria assessed during this scenario are listed in Table 3-5.

Table 3-5 Criteria Assessed During Operational Scenario 5

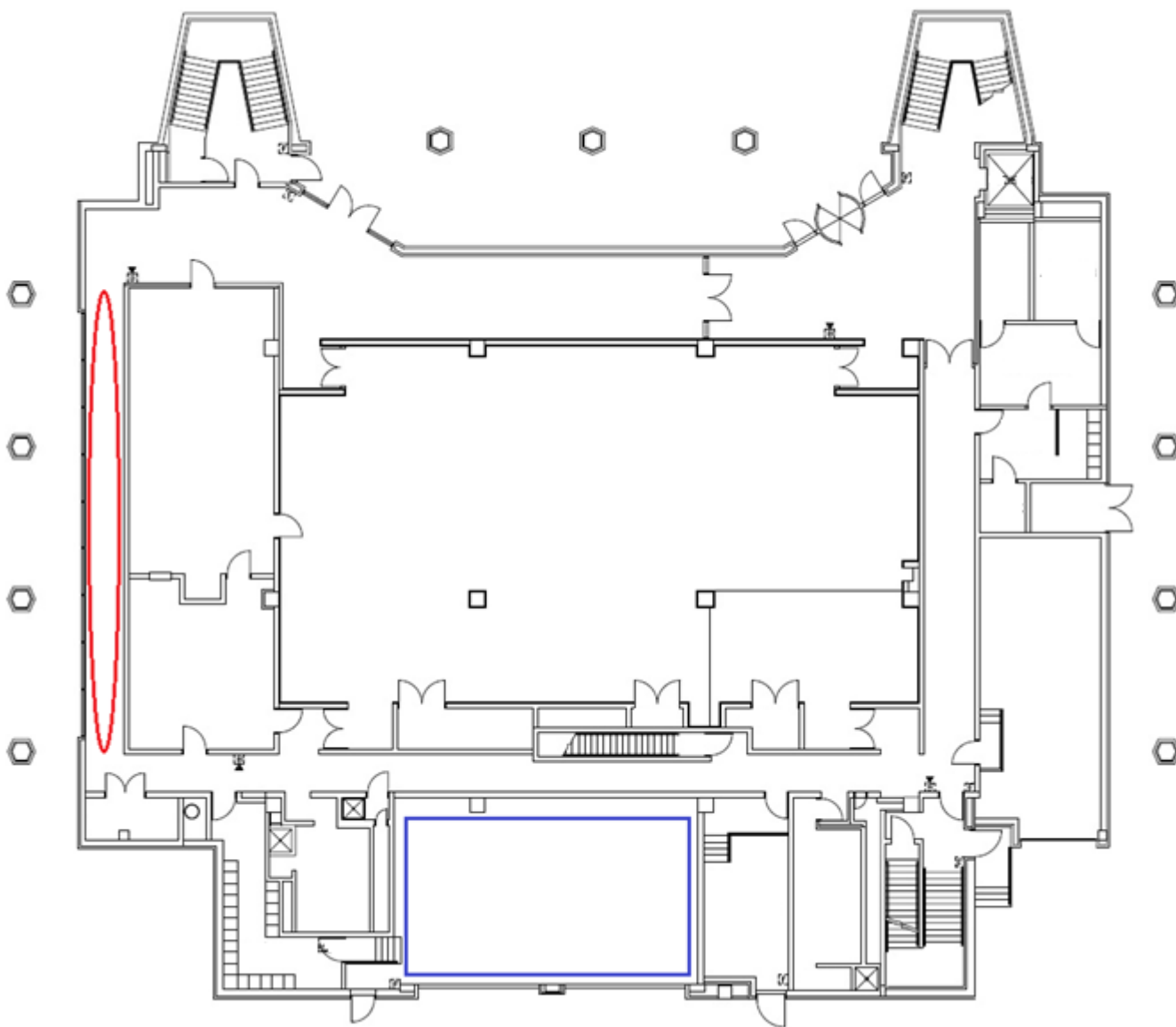| Evaluation Criteria |
| --- |
| Antenna Options |
| Channel Capacity |
| Power Level/Range |
| Power Source Options |
| Audio/Voice Clarity |
| Ease of Use in Field |
| Channel Selection |
| Ease of Setup Upon Arrival |
| Ease of Configuration |
| Internal Storage Space |
| Physical Weight |
| Size |
| Durability |

Figure 3-5 First Floor of FAB

The red oval indicates the repeater deployment location, and the blue rectangle indicates the location of the incident commanders during the USAR scenario.
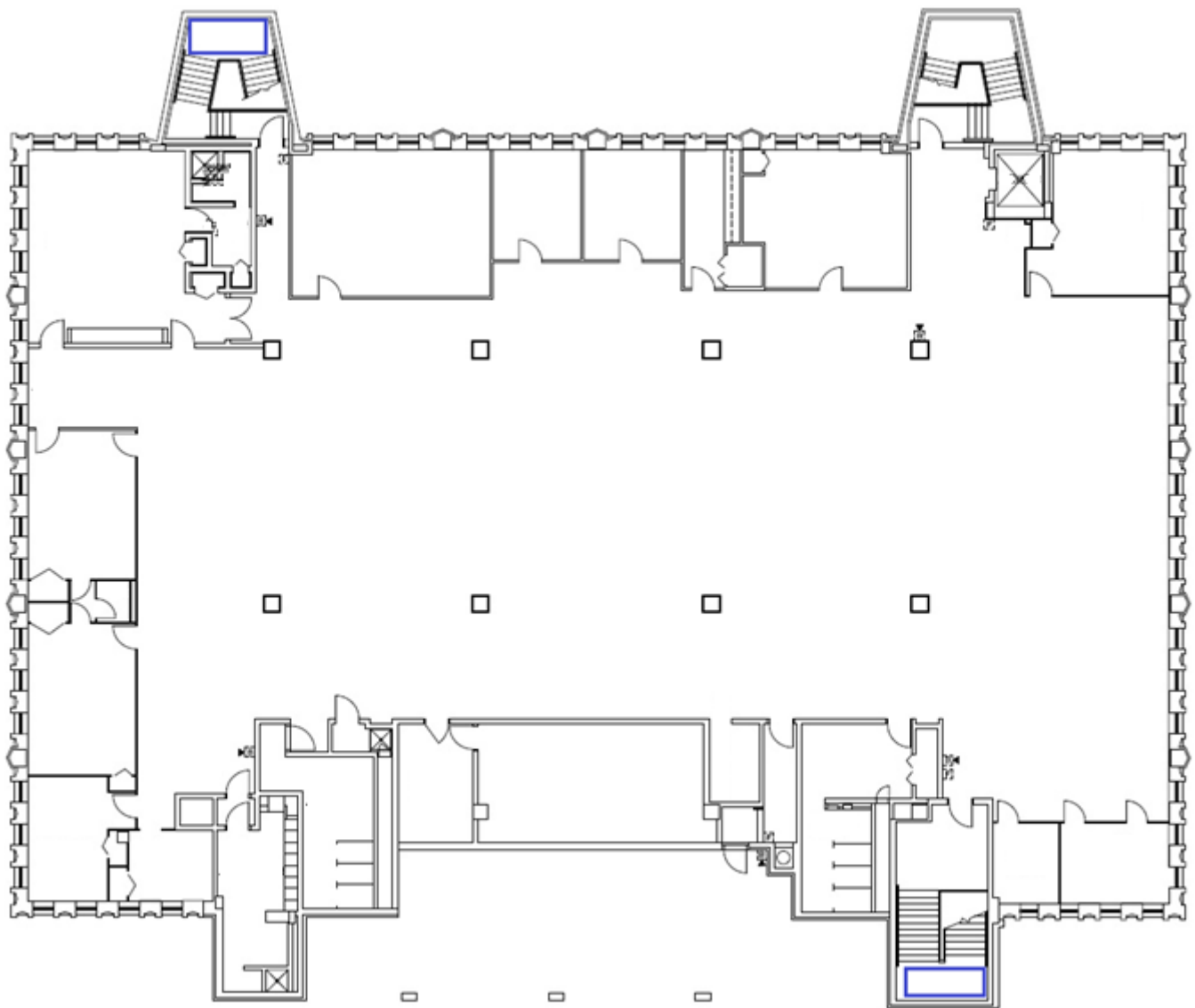
Figure 3-6 Second Floor of FAB

The blue rectangles indicate where the rescue teams were positioned during the USAR scenario.

3.3 Data Gathering and Analysis

After each scenario, the data collectors used a questionnaire to record the evaluators' scores for each product according to the evaluation criteria listed in Section 2.0. The questionnaire included specific questions for each criterion that the data collectors read to the evaluators, who then scored the criteria using the following 1-to-5 scale:

1) The product **meets none of my expectations** for this criterion.

2) The product **meets some of my expectations** for this criterion.

3) The product **meets most of my expectations** for this criterion.

4) The product **meets all my expectations** for this criterion.

5) The product **exceeds my expectations** for this criterion.

Once evaluators had completed all assessment activities, they had an opportunity to review their criteria ratings and comments for all products and adjust them as necessary. Data collectors captured evaluators' comments related to advantages and disadvantages of the assessed products as well as general comments on the assessed products and the assessment process.

After the event the NUSTL team calculated overall averaged assessment and category scores for each product using the formulas in Appendix C. The evaluators' comments were also reviewed and appear summarized in this assessment report.

4.0 ASSESSMENT RESULTS

Overall scores for the portable radio repeaters for indoor and subterranean environment ranged from 3.2 to 4.1. These overall assessment results are presented in Table 4-1 and Table 4-2. Additional details and evaluator comments on each product are provided in Sections 4.1 through 4.3.

Table 4-1 presents the overall assessment score and category scores for each product. Products are listed in order from highest to lowest overall score throughout this section. Calculation of the overall score uses the raw scores for each category, prior to rounding; products with the same overall score are listed in order based on the raw data.

Table 4-1 Assessment Results

Product	Overall Score	Overall	Capability	Usability	Deployability	Maintainability
Etherstack SFFR-6 GoBox		4.1	4.0	4.5	4.0	4.0
Codan Stratus		3.8	3.7	3.6	3.9	4.1
Motorola/Futurecom PDR8000		3.2	3.2	3.3	3.6	2.3

Key: 1 (least favorable) to 5 (most favorable)

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Table 4-2 presents the average scores that evaluators assigned to each of the evaluation criteria for the products. A green, fully shaded circle represents the highest rating, while a red, unshaded circle represents the lowest rating. Key specifications of each product as assessed are listed in Table 1-2.

Table 4-2 Evaluation Criteria Ratings

Key

Rating	Range
Lowest Rating (empty circle)	X<1.5
quarter-shaded (red)	1.5≤X<2.5
half-shaded (black)	2.5≤X<3.5
three-quarter-shaded (green)	3.5≤X<4.5
fully shaded (green) — Highest Rating	4.5≤X

Category	Evaluation Criteria	Codan Stratus	Etherstack SFFR-6 GoBox	Motorola/Futurecom PDR8000
Capability	Encryption*	three-quarter (green)	three-quarter (green)	three-quarter (green)
	Antenna Options	three-quarter (green)	full (green)	three-quarter (green)
	Battery Capacity	half (black)	half (black)	lowest (empty)
	Channel Capacity*	three-quarter (green)	three-quarter (green)	three-quarter (green)
	Power Level/Range	half (black)	three-quarter (green)	half (black)
	Power Source Options	three-quarter (green)	full (green)	quarter (red)
Usability	Audio/Voice Clarity	three-quarter (green)	full (green)	half (black)
	Ease of Use in Field	half (black)	full (green)	three-quarter (green)
	Channel Selection	three-quarter (green)	three-quarter (green)	half (black)
Deployability	Ease of Setup Upon Arrival	three-quarter (green)	full (green)	three-quarter (green)
	Ease of Configuration	three-quarter (green)	full (green)	three-quarter (green)
	Internal Storage Space	quarter (red)	lowest (empty)	quarter (red)
	Physical Weight	full (green)	three-quarter (green)	three-quarter (green)
	Size	full (green)	full (green)	three-quarter (green)
Maintainability	Component Replaceability*	full (green)	three-quarter (green)	quarter (red)
	Durability	three-quarter (green)	three-quarter (green)	quarter (red)
	In-House Maintenance*	three-quarter (green)	three-quarter (green)	quarter (red)
	Maintenance Frequency*	three-quarter (green)	three-quarter (green)	three-quarter (green)

* These criteria were assessed by specification only.

4.1 Etherstack SFFR-6 GoBox

The Etherstack SFFR-6 GoBox was assessed with ICOM IC-F7020T radios operating in the Ultra High Frequency (UHF) band, specifically the 400 MHz band. The repeater transmitted at 1, 5 or 15 watts at different times throughout the assessment.

Upon initial deployment, evaluators placed the repeater on the floor near a maintenance closet and placed the antenna in a vertical orientation on a stack of paper approximately 3 feet high. The repeater was set to transmit at 5 W. Field reconfigurations included raising the transmission power to 15 W, hanging the antenna from ceiling tiles in the basement, and placing the repeater and antenna at the top of a stairwell that reached the first floor of the FAB.

Evaluators gave the GoBox an overall assessment score of 4.1. Comments they provided throughout the assessment are reported below, grouped by SAVER category.

Figure 4-1 Etherstack SFFR-6 GoBox
Image Credit: Etherstack

4.1.1 Capability

The GoBox received a Capability score of 4.0. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Encryption:** The GoBox has passive encryption, as opposed to active. Evaluators from the fire services noted that the strength of encryption methods is a generally a low priority feature for their departments.

- **Antenna Options:** The GoBox is antenna agnostic and offers flexibility of options such as, magnetic mounts and flexible constructions for ease of deployment in wilderness operational environments (see Figure 4-6). Etherstack offers another repeater model with two antenna ports available with no duplexer needed. Evaluators liked the built-in connectors and the compact size of the antenna used in assessment but did not like that it was not co-located with the repeater.

- **Battery Capacity:** The battery life is 10 hours, but evaluators liked that the batteries were hot swappable which mitigated the issue. A battery life indicator is on an integrated display, which was well received by the evaluators (see Figure 4-7).

- **Channel Capacity:** The GoBox can save up to 100 presets and can be easily reprogrammed through a computer. This repeater cannot use multiple channels concurrently. Evaluators noted that the PC interface was intuitive, and it was easy to search through presets for needed channels. However, evaluators were not able to adjust bandwidth of channels with the limited training provided during the assessment.

- **Power Level/Range:** The power level can be set to several discrete settings: 1, 2, 5, 12 or 15 watts (see Figure 4-7). This provides sufficient coverage, but more options in this range are desired by evaluators. The power level and range are strongly dependent on the location of the repeater and antenna. Evaluators noted that this could hinder redeployment.

  It should be noted that this repeater was assessed with radios in the UHF band, which were at a lower frequency than those for other products. In ideal and identical conditions, an RF signal at a lower frequency will travel further than one at a higher frequency. Additionally, due to the use of the UHF band, this repeater likely experienced less interference from the outdoor structures in the parking lot across the street from the FAB.

- **Power Source Options:** The GoBox offers several power source options, including hot swappable batteries with a battery life indicator and AC power. The repeater also has a port for DC power but lacks a universal power cord.

Another five criteria in the Capability category were deemed "information only." These criteria did not contribute to the product's score, but the assessment team did record evaluator on these criteria:

- **Data and Video:** The GoBox offers P25 data and GPS but not video transmissions.

- **Intrinsic Safety:** It is not intrinsically safe. Evaluators from the fire department noted that this is not ideal for their profession.

- **Monitoring and Alerting:** There is no audible battery alert. Evaluators remarked that the battery life indicator on the integrated display is not easy to see or read at a distance. The indicator and display are also not visible with the lid closed (see Figure 4-7).

Figure 4-2 Evaluator with Etherstack Repeater and Antenna Hung from Ceiling Tiles

- **Multi-Band Interoperability:** Interoperable only with for certain bands. Evaluators noted that it is not capable of supporting Philadelphia frequencies (800MHz).

- **Operating Mode:** The repeater is compatible with both analog and digital radios.

Figure 4-3 Integrated Display and Controls on Etherstack Repeater

Left to right: Display with power level and battery life indicator; on/off switches; knob for transmission power selection

4.1.2 Usability

Evaluators gave GoBox a Usability score of 4.5. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Audio/Voice Clarity:** Evaluators were impressed with the audio clarity, noting that it was the best clarity experienced in far distance even when windy. This is likely due to the frequency used with the assessed unit. The configuration of the GoBox unit used during the assessment used RF channels in the 400 MHz frequency band. Other repeaters assessed were configured to use channels in the 800 MHz band. In ideal and identical conditions, an RF signal at a lower frequency will travel further than one at a higher frequency. As a result of operating at a lower frequency, this repeater likely experienced less interference from the outdoor structures in the parking lot across the street from the FAB. It is also possible that audio signal processing on the ICOM handheld radios, which were supplied by the vendor representative and not PFD, provided an advantage over the audio signal processing on the PFD Motorola units. PFD Motorola radios could not be used to assess the GoBox because they could not be configured to transmit in the 400 MHz frequency band during the assessment.

- **Ease of Use in Field:** The integrated display can be used with the lid open and with only three buttons. Evaluators thought it was easy to use. The power button needs to be held down to turn it on or off, which prevents accidentally turning off the repeater. This repeater was the smallest; nevertheless, some evaluators perceived it as (surprisingly?) heavy for its small exterior dimensions. One evaluator thought it was awkward to carry, but still the best among the assessed products if one needed to carry a repeater over a long distance. One evaluator who was concerned it could get kicked or run over on the ground wanted to elevate the repeater on a tripod.

- **Channel Selection:** The GoBox does not offer channel scanning, but users can switch between presets.

4.1.3 Deployability

The Etherstack received a Deployability score of 4.0. Product information and evaluator feedback on evaluation criteria related to this SAVER category include:

- **Ease of setup upon arrival:** Evaluators thought that the GoBox was easy to set up due to its small size, simple power up procedure and easy to see indicators. Evaluators noted that the antenna agnostic feature of the product would also simplify set up.

- **Ease of configuration:** The graphical user interface (GUI) was simple and user friendly and the web interface was intuitive. Evaluators thought the cells and headers were clear and easy to fill in with clear labels.

- **Internal storage space:** The GoBox has no internal storage space within the unit itself. A separate, larger case to transport the repeater and its accessories is available for purchase, however, through Etherstack (see Figure 4-8).

Figure 4-4 Storage Case for Etherstack Repeater and Accessories

- **Physical weight:** The GoBox is the second heaviest product assessed. The GoBox is 8.5"L X 10.2"D X 7.8"H and weighs 19.8 lbs.

- **Size:** It is smaller than all other assessed repeaters.

4.1.4 Maintainability

The Etherstack received a Maintainability score of 4.0. Product information and evaluator feedback relevant to this SAVER category include:

- **Component Replaceability:** The modular construction allows for easy replaceability of individual components, including a proprietary duplexer. However, replacement components are only sold by Etherstack.

- **Durability:** The GoBox has no fans or ventilation ports, but it is equipped with fins for dissipating heat (similar to a plate fin heatsink that might be used in other electronic devices). A few evaluators expressed concern that the metal construction could lend itself to denting if the repeater itself were dropped if something were dropped onto the repeater. It is waterproof (IP67).

- **In-House Maintenance:** The GoBox can be maintained in house as long as one purchases the modular replacement components from Etherstack.

- **Maintenance Frequency:** The vendor recommends performing preventative maintenance, such as verifying the case's integrity, on an annual basis. Repeater programming and firmware updates can be conducted by connecting the repeater to a computer via a USB port and using a web-based software.

4.1.5 Affordability

All criteria in the Affordability category are "information only." These criteria did not contribute to the product's score. However, NUSTL data collectors recorded comments relevant to these criteria:

- **List Price:** The MSRP of the GoBox, as provided by the vendor at the assessment, is $25,000.

- **Contract Pricing:** It is not listed on GSA schedule.

- **Maintenance Costs:** Even though it is an Australian company, Etherstack does have maintenance engineers in New York City readily available, which allows them to offer lower shipping costs and quicker maintenance turnaround times (than competitors? Or than if you sent it to Australia?).

- **Warranty:** The base warranty lasts one year and includes parts and services. An extended warranty, with a duration of 3 years, is available for purchase.

4.2 Codan Stratus

The Codan Status P25/LTE Transportable Repeater was assessed using the Philadelphia Fire Department's Motorola APX6000 XE handheld radios, set to operate in the 800 MHz frequency band. It has a maximum transmission power of 30 watts in the VHF/UHF band and 25W in the 700/800 MHz band. It can support up to 32 channels.

Upon initial deployment evaluators placed the Codan Stratus next to a locker and placed a magnetic-mount antenna on top of the locker in a vertical orientation. Field reconfigurations included switching to the designated secondary channel and moving the repeater and antenna into the stairwell at the activity station.

Evaluators gave the Codan Stratus an overall assessment score of 3.8. Comments they provided throughout the assessment are reported below, grouped by SAVER category.

Figure 4-5 Codan Stratus
Image Credit: Codan Communications

4.2.1 Capability

The Codan Stratus received a Capability score of 3.7. Product information and evaluator feedback on evaluation criteria related to this SAVER category include:

- **Encryption** Passive encryption is standard with the Stratus though an optional active encryption module is available. One evaluator shared that the strength of encryption methods may be a lower priority in firefighting applications.

- **Antenna Options:** Several antennas are available for this repeater; evaluators saw having options as a positive. There is no external port for a second antenna; evaluators noticed that a duplexer is needed. The product's duplexer is swappable. Evaluators indicated that it was easy to attach and move the antenna with routing options for the antenna cable but noted the lack of protective enclosures for transporting antennas.

- **Battery Capacity:** The Stratus does not have an internal battery. The external battery has a life of 20 hours at 10% duty cycle.

- **Channel Capacity:** Evaluators reported the toggle switches and rotating dials made it easy to switch between preset channels. The repeater can be programmed with up to 64 channels, 32 transmit and 32 receive.

To configure the presets, however, a connection to an external computer is necessary. Evaluators mentioned this repeater would not be easy to reprogram on scene.

- **Power Level/Range:** Stratus offers limited transmission power options depending on the selected frequency. For example, the 800 MHz operation is fixed at 25 W with only two pre-set tiers available to adjust the level, while VHF is adjustable from 0.5 W to 30 W. Unfortunately, the first two evaluators were provided with the wrong antenna at the start of the assessment, which resulted in the first team giving this product it a lower score, compared to the subsequent evaluator teams' assessments. One of the two initial evaluators did get the opportunity to re-evaluate the Codan Stratus during the USAR scenario at the end of the assessment.

- **Power Source Options:** The Stratus has a DC connection input for solar power and an external battery pack is available (20 hours run time). The power source connector has been tested to MIL-STD-810. It does not offer the option to power the repeater by cigarette lighter and its batteries are not hot-swappable. The external battery is nearly the same size as the repeater and at 48 lbs., weighs more than the repeater itself.

There were also five "information only." criteria in the Capability category. "These criteria did not contribute to the product's score, but the NUSTL team recorded comments relevant for these criteria:

- **Data and Video:** The Stratus can transmit video and short message service (SMS) data via an optional LTE interface—a feature that the evaluators found it notable.

- **Intrinsic Safety:** No information was provided to comment on intrinsic safety.

- **Monitoring and Alerting:** A power button is located on the console, but no monitoring or alerting features are included in the GUI in the PC app. Evaluators noted that while there is. Two evaluators found LED indicators on the repeater very easy to use but others noted that it lacked indicators outside of the box and also has no battery or frequency channel display. The transmit and receive LEDs were the same color, which led to evaluators having difficulty in distinguishing between the two LEDs.

- **Multi-Band Interoperability:** A replaceable duplexer is available and can be used to program the repeater to mutual aid channels for interoperable communications with partner agencies.

- **Operating Mode:** The Stratus is compatible with both digital and analog radios, and no switch is needed. Materials from the manufacturer claim it can work with both types concurrently.

4.2.2 Usability

The Codan Stratus received a Usability score of 3.6. Product information and evaluator feedback on evaluation criteria related to this SAVER category include:

- **Audio/Voice Clarity:** Some evaluators found the Stratus transmitted and received clearly; for others, it did not operate properly. As previously noted, at the start of the assessment the wrong antenna was provided to the first two evaluators, which caused them to give this product a lower score. Only one of these evaluators had the opportunity to re-evaluate the Codan Stratus during the USAR scenario at the end of the assessment. The other evaluator's score, however, was not discounted since this issue is one that could occur during a real response operation.

- **Ease of Use in Field:** While the Status offers an LTE modem, that LTE modem does not allow for over-the-air-reprogramming. Instead, users need to connect via USB to a computer to reconfigure preset parameters. However, depending upon the end user's needs and supposing the pre-programmed settings are adequate for the use case then the on-scene channel adjustments would be simple.

- **Channel Selection:** The set-up process is managed through a web-based platform, making it possible to copy and paste channels in the software. Some evaluators liked this interface. Evaluators also found the 32 preset configurations impressive.

4.2.3 Deployability

The Codan Stratus received a Deployability score of 3.9. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Ease of Setup Upon Arrival:** Evaluators found the Stratus easy to set up once deployed to the incident scene (or the activity station). A red-light indicator shows that it is powered on, but evaluators noted that the dials do not light up. Still, evaluators found the Stratus's more mechanical interface (see Section 4.2) that incorporates switches and dials made it more easily deployable than to the other products.

Figure 4-6 User Interface on Codan Stratus

- **Ease of Configuration:** The evaluators commented on the simplicity of the GUI of the software for configuring the repeater prior to deployment. Evaluators found the drop-down menus were intuitive. Some evaluators mentioned they would like to have other data ports in addition to the RJ45.

- **Internal Storage Space:** The case/casing of this repeater offers no space for the required power supply. However, the case has document pouch in its lid (see Figure 4-3). For transporting the power supply and accessories separate pelican case is needed. Some evaluators noted this is problematic because it introduces the risk of leaving the power supply (see Figure 4-4) behind; other evaluators found 2 boxes acceptable.

- **Physical Weight:** The Stratus weighs 32 pounds. Evaluators found it light and easy to transport.

- **Size:** Its dimensions are 15 x 9 x 7 inches. The size allows the repeater to be easily accommodated in a vehicle for transport.
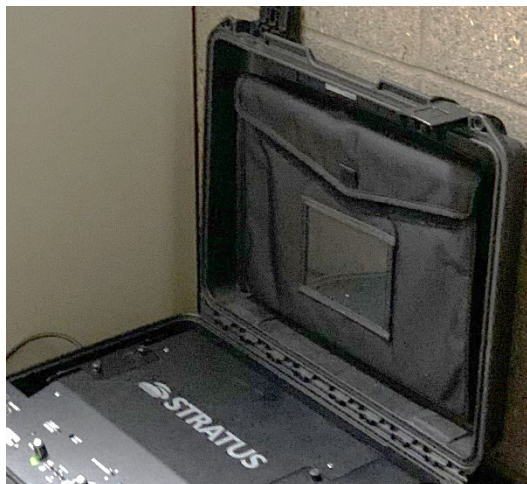
Figure 4-7 Document Pouch in Lid of Codan Stratus

Figure 4-8 Codan Stratus Power Supply

4.2.4 Maintainability

The Codan Stratus received a Maintainability score of 4.1. Product information and evaluator feedback criteria related to this SAVER category include:

- **Component Replaceability:** Modular replacements are available, and both the LTE modem and duplexer can be added and replaced.

- **Durability:** Some evaluators found the connection caps and the IP65-rated case sufficiently durable, while others remarked that the level of liquid ingress protection would likely be insufficient. While the product can be operated with the case closed, evaluators noted that is only at a low duty cycle (10-15%) of radio transmissions. They stated that in bad weather conditions, the case would have to be closed and felt it would probably overheat.

- **In-House Maintenance:** A one-day virtual or in-person training is offered on performing in-house maintenance. Evaluators found the on-screen diagnostics via PC useful.

- **Maintenance Frequency:** Evaluators deemed the recommended annual maintenance frequency acceptable.

4.2.5 Affordability

All criteria in the Affordability category are "information only." These criteria did not contribute to the product's score, but the NUSTL team still recorded responder comments were regarding these criteria:

- **List Price:** List price was not provided by the vendor during the assessment. However, the SAVER Market Survey Report on portable radio repeaters lists the MSRP of the Codan Stratus at $29,500 [3].

- **Contract Pricing:** Contract pricing is available.

- **Maintenance Costs:** No upfront maintenance costs are associated with product.

- **Warranty:** A 3 year and an extended (how long?) warranty option are offered. Evaluators said they consider 3–5 years typical.

4.3 Motorola/Futurecom PDR8000

The PDR8000 Portable Digital Repeater was assessed at 10W and 20W power levels, while using Motorola APX6000 XE radios owned by PFD and operating in the 800 MHz frequency band.

For the initial deployment, evaluators placed the repeater on the floor near the elevator and placed a magnetic-mount antenna horizontally on a window frame. The repeater transmitted at 10 W under this configuration. Field reconfigurations included moving the antenna to the elevator frame and increasing the transmission power to 20 W.

Evaluators gave the PDR80000 received an overall assessment score of 3.2. Evaluator comments provided throughout the assessment are reported below, grouped by SAVER category. Note that one evaluator was unavailable to assess the PDR8000.

Figure 4-9 Motorola/Futurecom PDR8000
Image Credit: Motorola Solutions

4.3.1 Capability

Evaluators gave the PDR8000 Portable Digital Repeater a Capability score of 3.2. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Encryption:** The PDR8000 allows for passive encryption but not active encryption. The majority of the evaluators indicated that the PDR8000 Portable Digital Repeater met all of their expectations for this evaluation criterion.

- **Antenna Options:** Any antenna can be used if it has a compatible connector, but an omni-directional antenna is recommended by the manufacturer. All evaluators indicated that the antenna options met all of their expectations. Some evaluators liked the recessed panel configuration as shown in Figure 4-10 because it protected the connection points.

Figure 4-10 PDR8000 Portable Digital Repeater Recessed Connection Points

(antenna port circled)

- **Battery Capacity:** to This repeater has no internal battery, which could limit deployment in outdoor environments or in the event of a power outage. A back-up battery with an estimated battery life of four hours is available as an optional purchase but information on the usage condition was not provided. All evaluators indicated that the battery capacity met none or just some of their expectations. An evaluator stated that this could support a response operation but would not be sufficient for a full shift.

- **Channel Capacity:** The PDR8000 can provide 10 deployment banks of 64 channels each, allowing for 640 preset channels. All evaluators indicated that the channel capacity either met all or exceeded their expectations.

- **Power Level/Range:** The power level can be programmed into channel presets using a computer but the power level cannot be adjusted on the repeater itself. The evaluators had mixed feedback on this criterion, which ranged from meeting some of their expectations to meeting all of them. The evaluators who indicated that the PDR8000 Portable Digital Repeater met most of their expectations attributed it to the power levels having to be programmed in advanced via computer. One evaluator who indicated the that the repeater met some of their expectations attributed it to the signal degradation experienced over a short distance.

- **Power Source Options:** The repeater has a 12V power option but not an internal battery; a limited alternate power options available. While the repeater comes with a power cord, the cord is not a COTS product, which would limit the ability replace it during field operations. Evaluators noted that the short length of the included power cord (approximately six to eight feet) could be a limitation during deployment. Still, two evaluators noted that the locking mechanism on the power cord would assist in preventing accidental unplugging. The majority of the evaluators indicated that the power source options met some or none of their expectations. Two evaluators said the power source options did meet their expectations noting that a 12V option for external was sufficient for their operations.

There were also five criteria in the Capability category that are "information only." These criteria did not contribute to the product's score, but the NUSTL team recorded evaluator regarding these criteria:

- **Data and Video:** The PDR8000 can transmit data, including SMS messages but does not have built-in video capability. One evaluator indicated that the ability to transmit data, especially SMS messages, could be a useful feature as it could assist with mitigating voice congestion on radio channels or in instances when radio silence is necessary.

- **Intrinsic Safety:** The repeater is not intrinsically safe.

- **Monitoring and Alerting:** The display on this product incorporates LED indicators and buttons as well as a visual display. One evaluator noted the display required menu diving to see the frequency or transmission power level. This evaluator commented that these parameters should be presented in the default display. One evaluator indicated that there more LED indicators on this product than others, and they appreciated the integrated display and raised buttons. Other evaluators noted that there were no exterior lights on the product, which would limit their ability to monitor when the repeater housing is closed.

- **Multi-Band Interoperability:** In order to achieve multi-band interoperability, separate units would need to be strung together. Duplexers can be swapped out and would allow for interoperable frequencies, including mutual aid channels.

- **Operating Mode:** The PDR8000 can be configured to allow compatibility with both analog and digital radios.

4.3.2 Usability

Evaluators gave PDR8000 Portable Digital Repeater Usability score of 3.3. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Audio/Voice Clarity:** All evaluators indicated that the audio and voice clarity of the repeater met most or all of their expectations.

- **Ease of Use in Field:** The majority of evaluators indicated that the ease of use in the field met most or all of their expectations. They found that the interface controls allowed for ease of changes between presets and the lack of a power switch contributed to quick setup. One evaluator found that the PDR8000 Portable Digital Repeater met some of their expectations and attributed this to the need of a computer to adjust presets as well as the number of abbreviations in the light indicator panel making it complicated, while they appreciated the ability to change the contrast of the display. One evaluator suggested a one- or two-page document be developed and housed within the repeater as a quick look reference sheet for end users.

- **Channel Selection:** The preset selection interface is shown in Figure 4-11. The evaluators had mixed feedback on this criterion, which ranged from meeting some of their expectations to meeting all of them. All evaluators found it easy to switch between presets. The evaluators who indicated that the repeater met most of their expectations nevertheless noted that if users need to select a specific channel that was not already a stored preset, a computer would be required to add it. The evaluators who indicated that the repeater met all of their expectations also mentioned that menu navigation required to view frequencies was not intuitive.

Figure 4-11 PDR8000 Portable Digital Repeater Light Preset Selection Interface

4.3.3 Depoyability

Evaluators gave the PDR8000 Portable Digital Repeater a Deployability score of 3.6. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Ease of Setup Upon Arrival:** All evaluators stated that the repeater either met most or all of their expectations. Evaluators had different opinions about the absence of an on/off switch. One evaluator noted that this eliminates a step in the deployment process, while others noted that this could present a challenge as the power source in an emergency environment may be unknown. Another evaluator described it as "plug and play" but noted that there are a lot of abbreviations on the repeater's LED indicators that would need to be remembered as shown in Figure 4-12.

Figure 4-12 PDR8000 Portable Digital Repeater Light Indicator Panel

- **Ease of Configuration:** The product can be programmed by using a USB cord to connect the repeater and a computer, which evaluators considered beneficial. Additionally, law enforcement can use a mobile data terminal to reprogram the repeater while on route to an incident. Evaluators found the configuration system easy to learn in a short amount of time All evaluators stated that the PDR8000 Portable Digital Repeater met either most or all of their expectations.
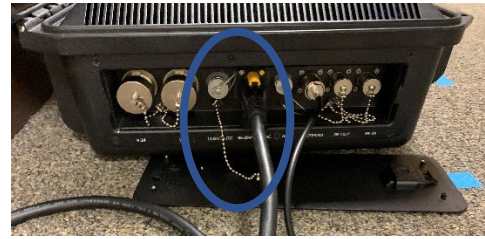

Figure 4-13 PDR8000 Portable Digital Repeater Chain Connecting Side Panel to Repeater

- **Internal Storage Space:** The repeater does not have designated locations for internal storage. Accessories can be placed inside the case, but they would shift during transport. One evaluator suggested adding Velcro or pockets into the lid of the repeater to keep accessories organized and in place. The majority of the evaluators indicated that the repeater met some of their expectations and two evaluators stated that the repeater met none of their expectations. One evaluator indicated that the internal storage space met most of their expectations noting that the power cord and antenna could be broken down and stored in the repeater enclosure. In response, another evaluator expressed that in that case caution should be used to ensure the cables are not damaged in the process (e.g., getting pinched between the base and lid upon closure).

- **Physical Weight:** The PDR8000 Portable Digital Repeater weights approximately 27 pounds. All evaluators indicated that the weight of met most, all, or exceeded their expectations. One evaluator suggested that adding wheels to the case could enhance its deployability.

- **Size:** The PDR8000 has exterior dimensions of 19.2"L x 15.2"D x 7.3"H. All evaluators indicated that the size of the repeater met most of, all, of exceed their expectations.

4.3.4 Maintainability

The PDR8000 received a Maintainability score of 2.3. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Component Replaceability:** This repeater has no local servicing locations. The evaluators had mixed feedback on this criterion, which ranged from meeting most of their expectations to meeting none of them. The majority of evaluators indicated that the PDR8000 met most or some of their expectations. Two evaluators indicated that the repeater did not meet any of their expectations because the device would need to be shipped to Canada for component replacement.

- **Durability:** This repeater is not waterproof. It includes a cooling fan without venting of the external case and a removable side panel protects the recessed connectors. The evaluators feedback on durability ranged from met all of their expectations to none of their expectations. Evaluators who said the repeater did not meet expectations cited its lack of waterproofing and that the protective side panel lacked in sturdiness (i.e., it was made of thin material and attached with a single chain as shown in Figure 4-13).

One evaluator noted that attaching the side panel via a hinge would enhance the durability and mitigate the risk of that panel becoming lost. During one assessment activity, a chain broke off of a connector cap; evaluators found it challenging to get the panel closed without interference from the loose chain.

- **In-House Maintenance:** When maintenance and repairs are needed the repeater must be shipped to Canada for servicing. The evaluators also had mixed feedback on this criterion, which ranged from meeting most of their expectations to meeting none of them. Those evaluators that stated the PDR8000 met some or none of their expectations attributed their rating to the need to ship it away.

- **Maintenance Frequency** Manufacturer recommended maintenance frequency is annual All evaluators indicated that either met most or all of their expectations.

4.3.5 Affordability

All criteria in the Affordability category are "information only." These criteria did not contribute to the product's score. However, NUSTL team members recorded evaluator comments regarding these criteria:

- **List Price:** Pricing of the PDR8000 was not readily available during the assessment. Based on previous research conducted by NUSTL, the PDR8000 has an MSRP of $15,986 that includes power supply, VHF duplexer, black suitcase, and unity gain antenna. Final pricing depends upon the selected configuration and warranty options [3].

- **Contract Pricing:** The repeater is available for purchase through a GSA schedule.

- **Maintenance Costs:** Maintenance costs are determined on a case-by-case basis.

- **Warranty:** Purchase of the PDR8000 comes with an eighteen-month warranty that covers parts and services. Extended warrantees are available for purchase in annual intervals.

5.0 SUMMARY

In September 2021, NUSTL, in conjunction with PNNL, conducted a SAVER assessment of portable radio repeaters for indoor and subterranean environments at the Philadelphia Emergency Operations Center. Eight first responder evaluators assessed the capability, usability, deployability, and maintainability of three commercially available portable radio repeaters against a set of 27 criteria. Table 5-1 summarizes the advantages and disadvantages of each product as identified by the evaluators. Evaluators also assessed a fourth product, the BK Technologies Rapid Deployment Portable Repeater (RDPR). Evaluators did not consider this product to be a standalone repeater and recommended separating the product's results from the others: results for the BK Technologies RDPR are found in Appendix B.

Individual responder agencies that intend to purchase portable radio repeaters for indoor and subterranean environments should carefully research the capabilities and features of available instruments to identify the product best suited to their operational needs.

Table 5-1 Advantages and Disadvantages

Manufacturer/Product		Advantages	Disadvantages
	Etherstack SFFR-6 GoBox	• Small size • Antenna agnostic • Hot swappable batteries • Modular construction allows for easy component replacement	• Battery life is 10 hours • Not intrinsically safe • No internal storage spaces • Limited RF spectrum supported (only VHF and low UHF)
MSRP: $25,000	Overall Score: 4.1		
	Codan Stratus	• Toggle switches and dials easy to use • In-house maintenance with a 1-day virtual or in-person training, with an on-screen diagnostic on the PC interface	• No internal battery • Limited transmission power options depending on frequency • Power supply is large and external to the repeater, requiring a separate case for transport
MSRP: $29,500*	Overall Score: 3.8		

Manufacturer/Product		Advantages	Disadvantages
Motorola/Futurecom PDR8000		• Quick and easy setup, described as "plug and play" due to the lack of an on/off switch • Number of presets available (640) • Recessed connection points (antenna, power, etc.) • Easy to switch between presets • USB port used for programming	• No internal battery • Limited life (4 hours) of optional external back-up battery • Lack of local maintenance and repair options • Power level changes cannot be done on the repeater (only programmable via computer) • Lack of internal storage space
MSRP: $15,986*	Overall Score: 3.2		

*MSRP was not provided by the vendor representative during the assessment. The value listed was taken from the SAVER Market Survey Report on Portable Radio Repeaters for Indoor and Subterranean Environments [3].

6.0 ACKNOWLEDGEMENTS

7.0 REFERENCES

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[2] H. Shahid, R. Bartholomew, K. Dooley, J. Ellis, M. Monetti, R. Ozanich and R. Pratt, "Portable Radio Receivers for Indoor and Subterranean Enviornments Assessment Plan," U.S. Department of Homeland Security Science and Technology Directorate, 2021.

[3] International Telecommunications Union, "P.863: Perceptual objective listening quality prediction," 13 October 2021. [Online]. Available: https://www.itu.int/rec/T-REC-P.863. [Accessed 2022].

[4] Institute of Electrical and Electronics Engineers, "IEEE Recommended Practice for Speech Quality Measurements," *IEEE,* no. 297, 1969.

[5] H. Shahid, R. Bartholomew, K. Dooley, J. Ellis, M. Monetti, M. Norman, R. Ozanich and R. Pratt, "Portable Radio Repeaters for Indoor and Subterranean Environments Market Survey Report," U.S. Department of Homeland Security Science and Technology Directorate, 2021.

Appendix A. Evaluation Criteria Definitions

The focus group identified 28 evaluation criteria, which were then sorted into the SAVER program's five established categories. The criteria for this assessment are defined as follows.

The **Capability** groups criteria related to product features or functions needed to perform one or more responder-relevant tasks. Six capability criteria to be assessed were identified and defined by the focus group:

- **Encryption.** Repeater can passively retransmit encrypted data, including AES-256 encrypted data, without decryption to other users on the network. [2] Active encryption is the process of decrypting and re-encrypting the signal at the repeater either with the same key/encryption algorithm or a different one. To allow active encryption, the encryption/decryption keys need to be available at the repeater, possibly requiring physical control of the repeater to ensure security. Active encryption and on-board encryption are desired but not required[3].

- **Antenna Options.** Different antennas (including omnidirectional antennas, directional antennas and antenna arrays) can be used with the repeater for different applications. Antenna connectors are universal and built into the repeater's protective enclosure.

- **Battery Capacity.** Internal and/or external batteries and power sources last throughout a shift or response operation under intensive usage conditions.

- **Channel Capacity.** Repeater bandwidth allows for usage of multiple narrowband or wideband voice-only channels. Channel bandwidth can be adjusted between 12.5 kHz and 25 kHz for different applications.

- **Power Level/Range.** The transmission power level and receiver sensitivity of the repeater allow for sufficient coverage range specific to the application. Power output level is adjustable as necessary. Coverage range of the repeater may be dependent on the transmission power level and receiver sensitivity of other communications equipment, such as handheld tactical radios that are used with the repeater.

- **Power Source Options.** Multiple power source options are available. This may include solar power, internal batteries, vehicle auxiliary power (e.g., a cigarette lighter) or AC power. The repeater is equipped with universal connectors for external power sources. Product contains at least 2 power sources operating in parallel to avoid downtime in case of battery failure (hot swappable batteries). External or removable power sources are light enough to be carried by one person.

The focus group also identified and defined five information only capability criteria:

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[2] The Advanced Encryption Standard (AES) is a widely used standard for data security developed by the National Institute of Standards and Technology (NIST). AES-256 is a form of AES that uses encryption keys with a length of 256 bits.

[3] Passive encryption refers to the retransmission of an encrypted signal without decrypting or re-encrypting the signal. Active encryption refers to decrypting a received signal and then re-encrypting it before retransmission. Depending on how it is implemented, active encryption may allow for interoperable communications and may allow an authorized user to use the repeater as a handset. However, active encryption may create a more complex communications system and presents a risk of unauthorized access at the point of the repeater.

- **Data and Video.** The repeater can retransmit data and video signals.

- **Intrinsic Safety.** The repeater and any accessories may be operated in potentially explosive environments. The product complies with the Underwriters Laboratory (UL) 913[4] standard or other application standards for intrinsic safety.

- **Monitoring and Alerting.** An intuitive integrated or remote display allows for monitoring of repeater parameters (e.g., frequency and power), status (e.g., remaining battery life and active status) and usage (radio traffic). Integrated displays can be used easily in low light environments. Repeater provides visual and audible low battery life alerts.

- **Multi-Band Interoperability.** The repeater can be tuned to different frequency bands (including the Very High Frequency (VHF) band, the Ultra High Frequency (UHF) band, and the 700/800-Megahertz (MHz) band) to allow for interoperable communications. The repeater is equipped with a duplexer.

- **Operating Mode.** The repeater is compatible with both digital and analog radios.

Usability groups criteria related to ergonomics and the relative ease of use when performing one or more responder-relevant tasks. Four usability criteria were identified and defined by the focus group.

- **Audio/Voice Clarity.** The audio clarity of repeated signals is appropriate for operational usage.

- **Compatibility with Fixed Infrastructure.** The repeater can supplement fixed communications infrastructure without creating interference. This criterion was not assessed.

- **Ease of Use in Field.** This refers to usage of the repeater after initial deployment on the incident scene. Repeater parameters can be adjusted through an intuitive integrated or remote interface after initial deployment if necessary. Specialized technicians are not required to adjust parameters. The repeater can be used easily in low-light environments and while wearing heavy personal protective equipment (PPE), such as Level A HazMat suit.

- **Channel Selection.** Users can save frequency presets for instant tuning [channel selection]. The repeater can scan for empty and occupied channels. Since none of the products assessed included a scanning feature, products were not evaluated against this portion of the criterion.

Deployability groups criteria related to preparation to use the product, including transport, setup, training, and operational/deployment restrictions. Five deployability criteria were identified and defined by the focus group.

- **Ease of Setup Upon Arrival.** This refers to the initial deployment of the repeater on the incident scene. Installing the repeater on the incident scene is easy and can be completed within one hour. This includes setting up antennas and power sources. Parameters are easy to adjust as necessary. The repeater can be used easily in low-light environments.

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[4] The UL913 Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division 1, Hazardous (Classified) Locations describes requirements for intrinsically safe equipment to be operated or installed in potentially explosive environments.

- **Ease of Configuration.** This refers to ease of use prior to arriving on scene. Minimal training is required to configure the repeater for deployment on an incident scene. Repeater parameters (such as frequency or transmission power) can be configured in a radio workshop or on route to an incident scene. The repeater uses universal computer connectors for reprogramming.

- **Internal Storage Space.** The enclosure has designated compartments for stowing accessories, such as antennas or power cables. This feature is ideal for quick deployments or shorter operations.

- **Physical Weight.** The repeater is light enough to be carried by one or two people (i.e., less than 50 pounds). The enclosure is equipped with wheels if it is more than 50 pounds.

- **Size.** The outer dimensions of the repeater are small enough to allow for transporting in vehicles or by one or two people.

Maintainability groups criteria related to the routine maintenance and minor repairs performed by responders, as well as included warranty terms, duration, and coverage. Four maintainability criteria were identified and defined by the focus group.

- **Component Replaceability.** A single component, rather than the entire system, can be replaced in the case of component malfunction or failure.

- **Durability.** The repeater has ruggedized features. This may include a heavy plastic, rather than metal, construction of the protective enclosure; covers for antenna and power connectors when not in use; water proofing, water resistance or weather sealing (i.e., ingress protection rating of IP67[5] or higher rating or equivalent); drop or shock proofing (i.e., compliant with MIL-STD-810G[6]); and ventilation ports or cooling fans.

- **In-House Maintenance.** Regular preventative maintenance, inspections and component replacements can be performed by technicians within the user's agency or department, rather than having to be returned to the vendor or other approved service provider for maintenance.

- **Maintenance Frequency.** The vendor recommends the frequency at which regular maintenance must be performed (e.g., annually, quarterly, after each use). A product that needs to be maintained less frequently will receive a higher score for this criterion.

Affordability groups criteria related to the total cost of ownership over the life of the product. This total cost includes purchase price, training costs, warranty costs, recurring costs, and maintenance costs. Four affordability criteria were identified and defined by the focus group. All criteria in this category were deemed to be information only.

- **List Price.** This refers to the Manufacturer's Suggested Retail Price (MSRP). This does not include bulk discounts.

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[5] Ingress protection ratings are defined in the International Electrotechnical Commission (IEC) International Standard 60529, entitled Degrees of Protection Provided by Enclosures (IP Code). The first digit refers to the level of solid particle ingress protection and the second digit refers to the level of liquid ingress protection. An IP67 rating indicates that a product is dust tight and protected against immersion up to 1 meter.

[6] U.S. Military Standard MIL-STD-810, "Environmental Engineering Considerations and Laboratory Tests" provides testing methods and procedures to ensure equipment can be safely used in harsh environments. Although the latest version of the standard is MIL-STD-810H which was published in 2019, MIL-STD-810G published in 2008 is still widely accepted.

- **Contract Pricing.** The product is listed on a GSA schedule or other standing contracts between the vendor and the agency. The vendor meets state and local requirements for purchasing.

- **Maintenance Costs.** This refers to costs associated with maintenance, repairs and replacements.

- **Warranty.** A basic warranty is included with the purchase. Extended warranty plans are available.

Appendix B. BK Technologies Rapid Deployable Portable Repeater Results

During the assessment, evaluators suggested that results for the BK Technologies Rapid Deployable Portable Repeater (RDPR) be separated from the other products as the RDPR is not a standalone repeater. The RDPR relies on two handheld radios that are plugged into the repeater enclosure rather than built-in electronics for receiving and re-transmitting RF signals. Despite the differences in construction, the RDPR can provide the same functionality as a repeater and was thus still included in the assessment.

The RDPR is an audio bridge that connects two separate radios' networks by utilizing two discrete pre-configured handheld radios that are on the networks that need to be bridged. Two radio interface kits (RIKs) are used to integrate each discrete radio into the system. The RDPR also has a third external audio port for integrating a third network. The RDPR can be used with various frequency bands and channels as long as the radios have an audio interface that can be integrated into the RDPR.

Figure 7-1 Rapid Deployment Portable Repeater
Image Credit: BK Technologies

Many specifications, such as frequency, transmission power, receiver sensitivity and encryption methods of the RDPR are dependent on the portable radios used. RDPR has various RIKs for radios available that can integrate power, audio and mounting using a single mountable interface. RIKs for many common radios are available.

During the assessment, the RDPR was evaluated using a PFD Motorola APX 6000 XE operating on the 800 MHz frequency band, a BK Technologies KNG2-P800 operating in the 800 MHz frequency band and a BK Technologies KNG2-P150 operating in the VHF band. The product transmitted at 3W. Evaluators assessed configurations using antennas mounted on tripods in a vertical orientation, using magnetic-mount antennas placed on lockers in a horizontal orientation, and moving the product and antennas to the top of the stairwell reaching the first floor of the FAB.

When assessed against the set of evaluation criteria listed in Section 2.0, the BK Technologies RDPR received an overall assessment score of 3.8. Table 7-1, Table 7-2, and Table 7-3 provide a summary of scores for the RDPR. Evaluator comments provided throughout the assessment are reported below, grouped by SAVER category.

Table 7-1 BK Technologies RDPR Results
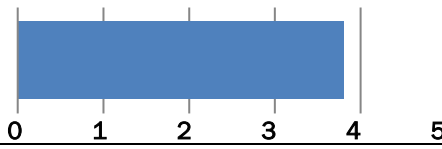
Product	Overall Score		Overall	Capability	Usability	Deployability	Maintainability
BK Technologies Rapid Deployable Portable Repeater	*(bar chart, scale 0 to 5, bar extends to ~3.8)*		3.8	3.6	3.8	4.0	3.9
Key: 1 (least favorable) to 5 (most favorable)							

Table 7-2 BK Technologies RDPR Evaluation Criteria Ratings

	Key			
	Lowest Rating ○	◔	◑	◕ ● **Highest Rating**	**Products**

Category	Evaluation Criteria	BK RDPR
Capability	Encryption*	◔
	Antenna Options	◕
	Battery Capacity	●
	Channel Capacity*	●
	Power Level/Range	◑
	Power Source Options	◕
Usability	Audio/Voice Clarity	◕
	Ease of Use in Field	◕
	Channel Selection	◕
Deployability	Ease of Setup Upon Arrival	●
	Ease of Configuration	◕
	Internal Storage Space	◑
	Physical Weight	●
	Size	●
Maintainability	Component Replaceability*	●
	Durability	◕
	In-House Maintenance*	◕
	Maintenance Frequency*	◕
* These criteria were assessed by specification only.		

Table 7-3 BK Technologies RDPR Advantages and Disadvantages

Manufacturer/Product		Advantages	Disadvantages
	BK Technologies RDPR	• Product is very easy to deploy • Internal battery is suitable for field deployments • Modular construction allows for easy maintenance • Regular maintenance focuses on handheld radios which agencies are already prepared for • Allows for interoperable communications between agencies if appropriate radios are installed	• Signal passed between embedded handheld radios is unencrypted, creating a risk of unauthorized access • Low transmission power of embedded handheld radios may not be sufficient for high-rise or sub-basement operations • No controls on the product itself for field reconfiguration; everything must be done through handheld radios
MSRP: $2,100*	**Overall Score: 3.8**		
* The MSRP of the BK Technologies RDPR is $2,100 without the RIK. The MSRP is $4,500 with the RIK.			

B.1 Capability

Evaluators gave the BK Technologies RDPR a Capability score of 3.6. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Encryption:** Encryption and decryption are dependent on the handheld radios and configurations used with the RDPR. An evaluator noted that the signal passing through the wired connection between the two radios is not encrypted even if the over the air signal on both the radios is encrypted. Based on evaluator comments the NUSTL team inferred that this product needs to be physically supervised or secured to prevent unauthorized access to the unencrypted signal. The majority of the evaluators indicated that the RDPR did not meet any or only met some of their expectations for this evaluation criterion.

- **Antenna Options:** Several options are available, allowing for flexibility in antenna setup. Options are relatively inexpensive. That said, antennas must be purchased separately per end users' requirements. The RDPR has a separate antenna port for each of the radios. A duplexer and an RF switch are available for product, if desired. Because the RDPR allows total customization of antennas, some evaluators felt it exceeded their expectations, while others indicated that it did not meet all their expectations because users are required to provide their own antenna.

- **Battery Capacity:** According to the vendor, battery life is approximately 18 hours under 50% duty cycle or 99 hours under 5% duty cycle At the assessment, battery capacity appeared lossless for at least one hour; capacity was 100% at end of one of the team's evaluation.

Note that the handheld radios embedded in the RDPR run off their own internal battery rather than the RDPR's battery; this leaves open the possibility of the product failing to function before the RDPR's battery is exhausted.

Evaluators liked the remaining battery life indicator because it would enhance awareness of when to prioritize a battery swap during field operations. However, they mentioned they could not see the indicator when the case was closed—which they considered a mild inconvenience but not a major drawback.

- **Channel Capacity:** Since the RDPR is not a standalone repeater, the channel capacity depends on the radios being used. Evaluators mentioned that in a mutual aid scenario, the number of available channels may be limited. Nevertheless, they also observed that all necessary channels within their own agency and mutual aid channels would be available to them during an incident response. Note that when scoring this criterion, some evaluators assumed this product was being used solely within their own organizations, rather than considering mutual aid applications.

- **Power Level/Range:** The power is dependent on radio and the configuration used on the radio. All power adjustments are done on the handheld radios used with this product. Evaluators mentioned the power level supplied by the assessed configuration may not be appropriate for multi-story buildings or buildings with multiple sub-basement levels. The majority of the evaluators said that the power level and range features of the RDPR met most of their expectations, though others that said it did not meet any of them.

- **Power Source Options:** The RDPR is equipped with an internal battery. The product also has a 12V input available to connect to another power source like a solar array or external battery, an option that evaluators liked. In order to take advantage of the 12V input, however, additional power connector developed by BK Technologies is required 12V input. Evaluators did not like that the product itself does not provide a backup battery nor have a universal power source connector.

Five criteria in the Capability category are "information only." These criteria did not contribute to the product's score. However, the NUSTL team recorded comments relevant to criteria.

- **Data and Video:** The RDPR has an audio gateway only. Neither data nor video functionality is available with the RDPR.

- **Intrinsic Safety:** The product is not intrinsically safe.

- **Monitoring and Alerting:** The remaining battery life and transmitting indicators are located inside of the box; as mentioned, evaluators noted that the indicators were not visible when the case was closed but did not consider this a significant drawback. Output power and frequency indicators are supplied by the handheld radios; evaluators thought the RDPR should have those indicators built into the product as well. Evaluators also suggested the RDPR should have a volume unit (VU) meter.

- **Multi-Band Interoperability:** Multi-band interoperability is available by using radios that are on different bands and radios are plug and play if an RIK is available. The RDPR will work with any radio as long as there is a way to connect its audio interface.

- **Operating Mode:** The RDPR is compatible with both analog and digital, as long as there is an analog audio interface on the radios being used.

B.2 Usability

Evaluators gave the BK Technologies RDPR a Usability score of 3.8. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Audio/Voice Clarity:** Evaluators noted that adjusting antenna placement improved audio signal quality. It was recommended that this product should provide a VU meter to assess audio input, as currently it needs to be monitored via radio.

- **Ease of Use in Field:** Feedback during the assessment indicated the RDPR is easy to use after initial set-up but is difficult to adjust. Adjustments to channel or transmission power need to be made through the handheld radios--something which would be difficult once initial set-up is completed due to the small size of the controls on the radios. Similarly, there is no way to adjust settings based on the radios when the product housing is closed. The RDPR has an optional 25-foot power cable available for purchase Some evaluators found this product very easy to use and saw an operational benefit optional 25-foot cable.

- **Channel Selection:** No features on the RDPR itself handle channel selection; instead, channel selection is conducted entirely on handheld radios. The evaluators gave mixed responses to whether the RDPR met their expectations regarding channel selection. The majority said it meets all or exceeds their expectation, but one indicated it did not meet any and another that it met some of their expectations.

B.3 Deployability

Evaluators gave the BK Technologies RDPR a Deployability score of 4.0. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Ease of Setup Upon Arrival:** Evaluators noted that the initial setup was very simple if the radios were pre-configured. Specific comments included: set up was completed in five minutes, the procedure was simple, and components were clearly labeled. Still evaluators also mentioned that swapping radio types could be time consuming. Some evaluators noted installing radios and RIKs were the most time-consuming tasks during "on scene" setup. If a second handheld radio is not available, users would have to wait for a second one to arrive on scene, especially during mutual aid scenarios.

Figure 7-2 Evaluator Installing RIK for Motorola Radio in RDPR

- **Ease of Configuration:** Configuration and reconfiguration need to be done on the radios (not the "repeater" itself). Two dedicated radios would be needed for use within the agency (as opposed to mutual aid scenarios). Evaluators liked that the product itself did not need pre-programming and that users are generally familiar with the radios that integrate with this product. Evaluators mentioned that prepping for the configuration was easy and could be done with the five-minute training included in the vendor presentation. For easy configuration, evaluators observed that agencies could dedicate handheld radios to the RDPR. Evaluators also noted that while their agencies would have RIKs for its own handheld radios (assuming the agency is also equipped with the RDPR), they may not necessarily be equipped with RIKs for partner agency radios in a mutual aid scenario.

- **Internal Storage Space:** No dedicated internal storage options are provided by the design of the RDPR. However, most of the smaller accessories such as wires and connectors can be placed inside the case. Larger components, such as antennas, cannot be placed inside the housing . Most comments on the product in this criterion were negative. Evaluators expressed concern that there is not any dedicated storage for the RIKs. They noted that if tripods are used, additional storage and transport equipment would be needed as well. Evaluators gave the internal storage space of the RDPR a wide range of scores from it did not meet any of their expectations to it met all them.

- **Physical Weight:** The RDPR is 15 lbs. itself and 17 lbs. with RIKs and radios installed, with the small sized case. All evaluators found it light and easy to transport, even with the radios installed. Nevertheless, any antennas, tripods, or power cables required for deployment may be significantly heavier and harder to transport.

- **Size:** The RDPR has a short profile: its dimensions are 16.2 x 12.7 x 6.6 inches and is expected to be easily accommodated in a vehicle for transport. Despite the small size of the RDPR case, antennas and tripods (and other required components which will not fit in the case) may be significantly larger and harder to transport. The majority of evaluators said that the size of the product exceeded their expectations.

B.4 Maintainability

Evaluators gave the BK Technologies RDPR a Maintainability score of 3.9. Product information and evaluator feedback on criteria related to this SAVER category include:

- **Component Replaceability:** The primary components (radios, cable and case) can be individually replaced. If the product or a component needs to be serviced, it would be sent to the vendor located in Florida. Evaluators noted the modular construction makes it easy to swap the battery and radios in the RDPR. and liked that product components are made in the United States, allowing for quicker shipping of replacement parts.

- **Durability:** The product is contained within a durable Pelican case that, while weatherproof, does not have an IP rating. The case does not provide storage space for antennas or tripods (if used) nor RIKs nor power cables, so users would have to rely on other means for protection when the product is stored and transported. The RDPR has no internal fan; evaluators mentioned the internal battery could contribute to overheating if the case is closed while in use.

- **In-House Maintenance:** The evaluators noted the only system components requiring maintenance are the handheld radios and the battery. Maintenance on the radios could be done in house by the agency's radio custodian. However, a technician is necessary for battery maintenance. The scoring for this criterion was quite wide among the evaluators; one believed it did not meet any of their expectations, the others' responses ranged from it met most expectations for in-house maintenance to it exceeded them.

- **Maintenance Frequency:** No regular maintenance is required for the product. The evaluators recognized that only the battery and radio would need routine maintenance. Regular maintenance on handheld radios used in the RDPR would be completed separately by the agency and at their usual frequency. The evaluators noted this product can essentially be kept on a shelf until needed.

B.5 Affordability

All criteria in the Affordability category are "information only." These criteria did not contribute to the product's score. However, the NUSTL team recorded comments relevant to these criteria:

- **List Price:** The BK Technologies RDPR has a list price of $4,500 (as provided by the vendor at the assessment) when purchased with an RIK. The list price without an RIK is $2,100.

- **Contract Pricing:** The product is available on GSA schedule and National Associated of State Procurement Officials (NASPO) schedule. BK is also capable of creating contracts with state-level organizations. The GSA price is $2,500 with an RIK and $1,400 without an RIK.

- **Maintenance Costs:** No upfront maintenance costs are associated with product. Projected routine maintenance costs are minimal (see above for comments regarding maintenance).

Warranty: A basic one year warranty is provided with the purchase and an extended is warranty available.

Appendix C. Assessment Scoring Formula

The overall score for each product was calculated using the product's averaged criterion ratings and category scores. An average rating for each criterion was calculated by summing the evaluators' ratings and dividing the sum by the number of responses. Category scores for each product were calculated by multiplying the average criterion rating by the weight assigned to the criterion by the focus group, resulting in a weighted criterion score. The sum of the weighted criterion scores was then divided by the sum of the weights for each criterion in the category as seen in the formula and example below:

<u>Category Score Formula</u>

$$\frac{\sum\left(Average\,Criterion\,Rating \times Criterion\,Weight\right)}{\sum\left(Criterion\,Weights\right)} = \begin{array}{c}Category\\Score\end{array}$$

<u>Category Score Example[7]</u>

$$\frac{\left(4.3 \times 4\right)+\left(5 \times 4\right)+\left(4 \times 3\right)+\left(4.5 \times 3\right)+\left(4.5 \times 3\right)}{4+4+3+3+3} = 4.5$$

To determine the overall assessment score for each product, each category score was multiplied by the percentage assigned to the category by the focus group. The resulting weighted category scores were summed to determine an overall assessment score as seen in the formula and example below:

<u>Overall Assessment Score Formula</u>

$$\sum\left(Category\,Score \times Category\,Percentage\right) = \begin{array}{c}Overall\,Assessment\\Score\end{array}$$

<u>Overall Assessment Score Example</u>

<u>*Capability*</u>		<u>*Usability*</u>		<u>*Affordability*</u>		<u>*Maintainability*</u>		<u>*Deployability*</u>		
$\left(4.0 \times 33\%\right)$	+	$\left(4.2 \times 27\%\right)$	+	$\left(4.2 \times 20\%\right)$	+	$\left(3.8 \times 13\%\right)$	+	$\left(4.5 \times 7\%\right)$	=	4.1

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[7] Examples are for illustration purposes only. Formulas vary depending on the number of criteria and categories assessed and the criteria and category weights.