System Assessment and Validation for Emergency Responders (SAVER)

Standoff Radiation Detectors Assessment Report

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SAVER

System Assessment and Validation for Emergency Responders

Prepared by the National Urban Security Technology Laboratory

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The cover photo and images included herein were provided by the National Urban Security Technology Laboratory with the exception of the photo image of the Detective-200 on page 2, which is courtesy of ORTEC.

FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercially available equipment and systems and develops knowledge products that provide relevant equipment information to the emergency responder community. The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency response equipment
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency response equipment.

SAVER Program 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?” These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. As a SAVER Program Technical Agent, the National Urban Security Technology Laboratory (NUSTL) has been tasked to provide expertise and analysis on key subject areas, including chemical, biological, radiological, nuclear, and explosive weapons detection; emergency response and recovery; and related equipment, instrumentation, and technologies. In support of this tasking, NUSTL developed this report to provide emergency responders with information obtained from an operationally oriented assessment of Standoff Radiation Detectors (SRDs), which fall under AEL reference number 07RD-04-SGND titled Detector, Gamma/Neutron, Standoff.

For more information on the SAVER Program or to view additional reports on SRDs or other technologies, visit www.firstresponder.gov/SAVER.

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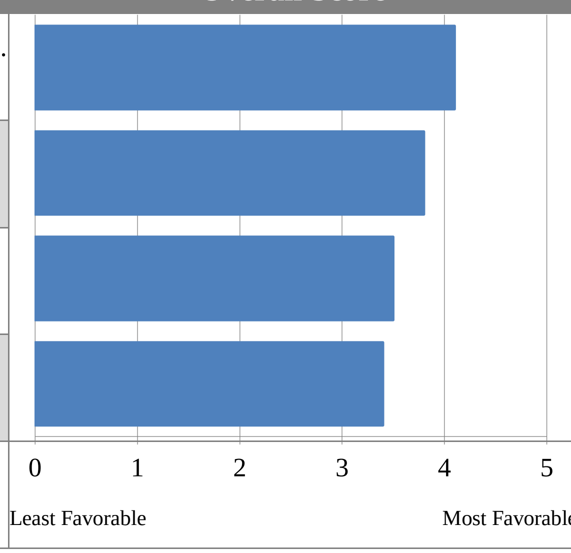
Standoff Radiation Detectors (SRDs) are vehicle-mounted radiation detection systems that can determine the direction of radiation sources and distinguish threats from background and normally occurring radiation. They are equipped with highly sensitive gamma and neutron radiation detectors so they can detect radioactive sources from a standoff distance that is appropriate for the application. By acquiring an energy spectrum of gamma radiation, SRDs can determine the radionuclide of source material and assess the threat level of radiation-related alarms. Emergency responders use SRDs for large-area searches, screening traffic at chokepoints, scanning traffic at patrolling speed, and scanning large storage facilities, among other applications.

In May 2015, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of SRDs. Four SRD products were assessed by emergency responders. The criteria and scenarios used in this assessment were derived from the results of a focus group of emergency responders with experience using SRDs. The assessment addressed 25 evaluation criteria in four SAVER categories: Capability, Deployability, Maintainability, and Usability. The overall results of the assessment are highlighted in the following table.

Product	Overall Score	Overall	Capability	Usability	Deployability	Maintainability
Bubble Technology Industries, Inc. FlexSpec Mobile		**4.1**	4.1	4.2	4.1	4.1
ORTEC Detective-200		**3.8**	4.0	3.4	4.2	3.9
Thermo Scientific, Inc. Mobile Matrix ARIS		**3.5**	3.5	3.2	3.7	4.2
Nucsafe, Inc. Portable Radiation Detection Kit		**3.4**	3.5	3.1	3.8	3.6



1. INTRODUCTION

Standoff Radiation Detectors (SRDs) are vehicle-mounted radiation detection systems that can determine the direction of radiation sources and distinguish threats from background and normally occurring radiation. They are equipped with highly sensitive gamma and neutron radiation detectors so they can detect radioactive sources from a standoff distance that is appropriate for the application. By acquiring an energy spectrum of gamma radiation, SRDs can determine the radionuclide of source material and assess the threat level of radiation-related alarms. Emergency responders use SRDs for large-area searches, screening traffic at chokepoints, scanning traffic at patrolling speed, and scanning large storage facilities, among other applications.

In May 2015, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of SRDs. The purpose of this assessment was to obtain information on SRDs that will be useful in making operational and procurement decisions. The activities associated with this assessment were based on recommendations from a focus group of emergency responders with experience using SRDs.

1.1 Evaluator Information

Seven emergency responders from various jurisdictions and with experience using SRDs volunteered to be evaluators for the assessment. Two of the seven evaluators were not able to evaluate all four products. Their comments are captured, but their scores are not included in the numerical results. Evaluator information is listed in Table 1-1. Prior to the assessment, evaluators signed a nondisclosure agreement, conflict of interest statement, photo release form, and informed consent form.

Table 1-1. Evaluator Information

Evaluator	Years of Experience	State
Lieutenant, Regional Police Department	20+	NY, NJ
Sergeant, County Police Department	20+	NY
Health Physicist, City Police Department	20+	NY
Lieutenant, City Fire Department	20+	NY
Detective, City Police Department, Emergency Services	20+	NY
Detective, City Police Department	11-15	NY
Lieutenant, Transportation Police Department	11-15	NY

1.2 Assessment Products

Four products were selected for the assessment based on the focus group’s recommendations. Each focus group member was asked to select four commercially available SRDs to assess and score them on a scale of 1 through 4, with the highest score given to the product that would be most preferred for the assessment. The four products with the highest total scores were selected for the assessment. The ORTEC Detective-200 was selected after another vendor declined to

participate. Three products were provided by the vendors, and the Thermo Scientific Mobile Matrix ARIS was provided by a participating responder agency.

Table 1-2 presents the products that were assessed.

Table 1-2. Assessed Products

Vendor	Product	Product Image
Bubble Technology Industries, Inc.	**FlexSpec Mobile**	
Nucsafe, Inc.	**Portable Radiation Detection Kit**	
ORTEC	**Detective-200**	
Thermo Scientific, Inc.	**Mobile Matrix ARIS**	

2. EVALUATION CRITERIA

The SAVER Program assesses products based on criteria in five established categories:

- **Affordability** groups criteria related 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** groups criteria related to product features or functions needed to perform one or more responder relevant tasks
- **Deployability** groups criteria related to preparing to use the product, including transport, setup, training, and operational/deployment restrictions
- **Maintainability** groups criteria related to the routine maintenance and minor repairs performed by responders, as well as included warranty terms, duration, and coverage
- **Usability** groups criteria related to ergonomics and the relative ease of use when performing one or more responder relevant tasks.

The focus group of emergency responders met in September 2012 and identified 49 evaluation criteria within the five SAVER categories defined above. They assigned a weight for each criterion's level of importance on a scale of 1 to 5, with 1 being of minor importance and 5 being of utmost importance. Each SAVER category was assigned a percentage weight to represent its importance relative to the other categories.

Products were assessed against 25 evaluation criteria within four SAVER categories; 24 other criteria recommended by the focus group, including the Affordability category criteria, were not assessed. Initial Cost, Maintenance Cost, Terms of Service Contract, Training Cost, Repair Cost, Trade-in Value/Disposal Options, Ruggedness, Connector Quality, Computer Compatibility, Quality of Customer Support, Software Updates, and Time that Vendor Supports Model were not assessed because these specifications are better assessed by individual agencies as part of the procurement process. Legally Defensible Data, Frequency of Repair, Amount of Downtime, Ease of Troubleshooting, and Service Location Flexibility were not assessed because sufficient information to assess these criteria was not available. Imaging Capability, Environmental Mode Capability, Remote Paging, and Training Mode were not assessed because all or some systems did not have these features. Command Center Connectivity, Resistance to Radio Frequency Interference, and Temperature Stability were not assessed because it would be impractical to assess these criteria during the current assessment.

Table 2-1 presents the evaluation criteria and their associated weights as well as the percentage weights assigned to the SAVER categories. Refer to Appendix A for evaluation criteria definitions. Because the criteria in the Affordability category were not assessed, this category was removed from the assessment. Only 2 of the 10 criteria in the Maintainability category were assessed; therefore, its category weight was reduced from the value assigned by the focus group[1] to 5 percent. To account for one fewer category and fewer criteria in other categories, the weights of the Capability, Usability, and Deployability categories were adjusted upwards to 50, 30, and 15 percent, respectively. Usability received a relatively high increase in weight because 9

[1] The original category weights assigned by the focus group were 30 percent for Capability, 25 percent for Affordability, 20 percent for Maintainability, 15 percent for Usability, and 10 percent for Deployability.

of its 11 criteria were operationally assessed. Deployability received a small increase in weight because the focus group assigned it a relatively smaller weight and because four highly weighted criteria from that category were not assessed.

Table 2-1. Evaluation Criteria

SAVER CATEGORIES				
Capability	**Usability**	**Deployability**	**Maintainability**	**Affordability**
Overall Weight 50%	Overall Weight 30%	Overall Weight 15%	Overall Weight 5%	Overall Weight 0%
Evaluation Criteria				
Gamma Detection Weight: 5	**Simplicity of Operation** Weight: 5	**Covert Operation** Weight: 5	**Legally Defensible Data** Not assessed	**Initial Cost** Not assessed
Neutron Detection Weight: 5	**Intuitive Display** Weight:4	**Power Source Options*** Weight: 5	**Frequency of Repair or Service** Not assessed	**Maintenance Cost** Not assessed
Radionuclide Identification Weight: 5	**Ease of Use in Moving Vehicle** Weight: 4	**Battery Operating Time*** Weight: 5	**Quality of Customer Support** Not assessed	**Terms of Service Contract** Not assessed
Detection Sensitivity Weight: 5	**Recall Mode** Weight: 4	**Vehicle Adaptability** Weight: 4	**Amount of Downtime** Not assessed	**Training Cost** Not assessed
Field-of-View Weight: 5	**Alarms** Weight: 3	**Equipment Size** Weight: 4	**Ease of Calibration** Weight: 3	**Repair Cost** Not assessed
Position Capability Weight: 4	**Misidentification Rate** Weight: 3	**Ruggedness** Not assessed	**Ease of Troubleshooting** Not assessed	**Trade-in Value/ Disposal Options** Not assessed
Reachback Capability Weight: 4	**Use by Single Operator** Weight: 2	**Environmental Specifications*** Weight: 4	**Modular Design** Weight: 2	
Source Localization Weight: 3	**Spectral Information Display** Weight: 2	**Connector Quality** Not assessed	**Time that Vendor Supports Model** Not assessed	
Wireless Capability* Weight: 2	**Training Mode** Not assessed	**Resistance to RF Interference** Not assessed	**Service Location Flexibility** Not assessed	
Remote Paging Not assessed	**Computer Compatibility** Not assessed	**Temperature Stability** Not assessed	**Software Updates** Not assessed	
Command Center Connectivity Not assessed				
Environmental Mode Capability Not assessed				
Imaging Capability Not assessed				

*Criterion was assessed by specification.

3. ASSESSMENT METHODOLOGY

The products were assessed at Brookhaven National Laboratory (BNL) over the course of 2 days. On the first day of the assessment, a facilitator presented a safety briefing and an overview of the assessment process, procedures, and schedule to the evaluators. Each product was then assessed in an operational environment. Specifications were provided for applicable criteria (wireless capability, power source options, battery operating time, operating temperature, and operating relative humidity), and the specifications were confirmed by the vendors.

During the operational assessment, evaluators assessed each product based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. Facilitators assisted the evaluators throughout the assessment, and vendor representatives were on hand to answer technical questions. The vendors provided an equipment familiarization session prior to each product assessment. Evaluators then assessed the products in two scenarios: (1) vehicle chokepoint and (2) large-area search. Evaluators did not drive the vehicles so that they could concentrate on the product's controls and displays during the assessment activities. Vendor representatives drove three of the vehicles, and an emergency responder, who was not acting as an evaluator, drove the vehicle containing the Mobile Matrix ARIS. Evaluators used the products one at a time and provided scores and comments for each product before assessing the next product.

3.1 Equipment Familiarization

Prior to each product assessment, vendor representatives conducted an equipment familiarization session with the evaluators that included an overview of the system's detectors, computers, display screens, and software. Vendors also trained the responders on how to best use the product, including, but not limited to:

- Turn on, set up, and initialize equipment
- Change or charge batteries (if applicable)
- Perform energy calibration (if needed)
- Set key performance parameters
- Set alarm parameters and silence an alarm
- Read displays and access display screens, including spectrum display
- Read Global Positioning System (GPS) data and use mapping capability[2]
- Download data.

Figure 3-1. Equipment Familiarization Session

[2] Mapping capability was evaluated as two separate criteria—Position Capability (displaying vehicle position on a map) and Recall Mode (displaying radiation data on a map linked to vehicle position and time).

3.2 Vehicle Chokepoint Scenario

Figure 3-2. Vehicle Chokepoint Scenario

Emergency responders often use SRDs to screen vehicles at traffic chokepoints such as the entrance to parking areas at high profile events. The vehicle chokepoint scenario simulated a chokepoint screening event. The SRDs were parked along the side of a single-lane roadway. Two SRDs were parked along each side of the road. A source truck was driven through the chokepoint, and evaluators determined the threat potential of the truck based upon whether or not the vehicle was emitting radiation, the type of radiation (gamma or neutron), and the radionuclide of the source material. Evaluators observed the SRD's radiation exposure rate compared to background radiation, audible and visual alarm indicators, radionuclide identifications, and spectrum displays to make their determination.

Table 3-1 lists the sources used during the chokepoint scenario. Each of the seven sources was a different radionuclide that could be identified by the SRD's radionuclide identification features. Four source radionuclides used are not in the standard American National Standards Institute (ANSI) N42.32 radionuclide library and therefore would not be identified by SRD systems that only follow the ANSI library. A californium-252 source was used to test the neutron detection capabilities of the SRDs, and a blank (no radiation source) was used to test for false-positive alarms. The sources were used one at a time, and a total of two sources were used for each of the four scenario rotations. After a source was loaded in the source truck, the truck was driven by the chokepoint at three different speeds. The procedure was then repeated with another source to complete the chokepoint rotation.

Table 3-1. Radiation Sources Used in Vehicle Chokepoint Scenario

Radionuclide	Gamma	Neutron	ANSI Library	Category	Notes
Cesium-134	✓			Medical	Common fission product
Cobalt-57	✓		✓	Industrial	Low-energy gamma emitter
Zinc-65	✓			Medical	
Barium-133	✓		✓	Industrial	
Californium-252	✓	✓		Industrial	
Yttrium-88	✓			Medical	
Cobalt-56	✓		✓	Industrial	High-energy gamma emitter

3.3 Large-Area Search Scenario

Figure 3-3. Large-Area Search Scenario

For the large-area search scenario, the SRD vehicles were driven around a course in which radiation sources were placed at various locations at the BNL facility. This scenario simulated an event in which responders search for a missing or stolen source. There were 10 target areas containing sources. In some cases, a target area contained the same source or sources as another target area, but the distance and shielding between the SRD and the source were different. The four SRD vehicles drove the course in procession and scanned the target areas for radiation one at a time. In each vehicle there was at least one vendor representative, one or two emergency responder evaluators, and an assessment facilitator who would also serve as a data collector.

At each target area, the SRD attempted to locate the source or sources and characterize its threat potential. The driver was allowed to maneuver the vehicle, and evaluators would take gamma spectra for up to 1 minute by setting the dwell time on the SRD software. Figure 3-3 shows an SRD approaching a target. In this case, the evaluators were told to scan the two visible faces of the gray building. There was a source placed at an undisclosed location along each building face.

The mobile detection exercises provided in this scenario tested criteria such as Detection Sensitivity, Field-of-View, Mapping Capability, Alarms, Source Localization, Simplicity of Operation, Intuitive Display, and Ease of Use in Moving Vehicle. It should be noted that all assessed systems operated with complex software that could operate in different modes and had many features that could be enabled or disabled with software settings. The assessment facilitator allowed the vendors to decide which modes and features should be enabled for each scenario. Vendors were briefed on which criteria would be scored. Evaluators were encouraged to ask questions about available features and request that systems be configured in various ways. Although most features were demonstrated during the course of the assessment, others remained disabled throughout the assessment because the vendor decided not to enable them and the evaluators did not request them. These instances are noted in the comment section for each product.

Table 3-2 lists the sources used during the large-area search scenario. Industrial radionuclides, medical radionuclides, naturally occurring radioactive material (NORM), special nuclear material (SNM), and neutron sources were present at various targets with sufficient activity to be detected by the SRDs being assessed.

Table 3-2. Radiation Sources Used in Large-area Search Scenario

Target Area	Source Material	Gamma	Neutron	ANSI Library	Category	Notes
1	Cobalt-60	✓		✓	Industrial	Heavily shielded
2	Highly enriched uranium	✓		✓	SNM	Present for all rotations
	Depleted uranium	✓		✓	Industrial	Present for rotations 1 – 2
	Thorium-232	✓		✓	NORM	Present for rotations 3 – 4
3, 4	Strontium-82 + Rubidium-82*	✓			Medical	Pure positron emitter with same signature as fluorine-18 and other pure positron emitters
5, 6	Cobalt-60	✓		✓	Industrial	
	Manganese-54	✓			Industrial	
7, 9	Radium-226 + Thorium-232 + Potassium-40	✓		✓	NORM	
8	Cesium-137	✓		✓	Industrial	Present for rotations 1 – 3
	Californium-252		✓		Industrial	Present for rotation 4
10	Cesium-137	✓			Industrial	
	Americium-Beryllium		✓	✓	Neutron source	

*Strontium-82 decays by electron capture to rubidium-82, which then decays by positron emission to stable krypton-82.

3.4 Data Gathering and Analysis

Each evaluator was issued a folder containing vendor-provided information, specifications, and product score sheets. Evaluators used the following 1 to 5 scale to score the criteria for each product:

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

Refer to Appendix A for evaluation criteria definitions and Appendix B for criteria scoring factors considered by the evaluators. Criteria with multiple scoring factors were assigned final overall scores by the evaluators. Facilitators captured comments related to each of the evaluation criteria as well as overall advantages and disadvantages of the assessed products. Once assessment activities were completed, evaluators had an opportunity to review their criteria ratings and comments for all products and make adjustments as necessary.

At the conclusion of the assessment activities, an overall assessment score, as well as category scores and individual criterion scores, were calculated for each product using the formulas referenced in Appendix C. In addition, evaluator comments for each product were reviewed and summarized for this assessment report.

4. ASSESSMENT RESULTS

Overall scores for the assessed products ranged from 3.4 to 4.1.

Table 4-1 presents the overall assessment score and the category scores for each product. Products are listed in order from highest to lowest overall assessment score throughout this section.

Table 4-2 presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. A red, unshaded circle represents the lowest rating.

Table 4-3 presents vendor-provided key specifications for the assessed products. The products were not purchased for the assessment and some vendors consider pricing information sensitive; therefore, the prices of the assessed SRDs are not given in this report. All assessed SRD systems have many different detector and vehicle options available at different prices. Agencies should contact the vendors for quotes for the systems described in this report or for systems configured with options that meet their needs.

Table 4-1. Assessment Results

Product	Overall	Capability	Usability	Deployability	Maintainability
Bubble Technology Industries, Inc. FlexSpec Mobile	**4.1**	4.1	4.2	4.1	4.1
ORTEC Detective-200	**3.8**	4.0	3.4	4.2	3.9
Thermo Scientific, Inc. Mobile Matrix ARIS	**3.5**	3.5	3.2	3.7	4.2
Nucsafe, Inc. Portable Radiation Detection Kit	**3.4**	3.5	3.1	3.8	3.6

Overall Score

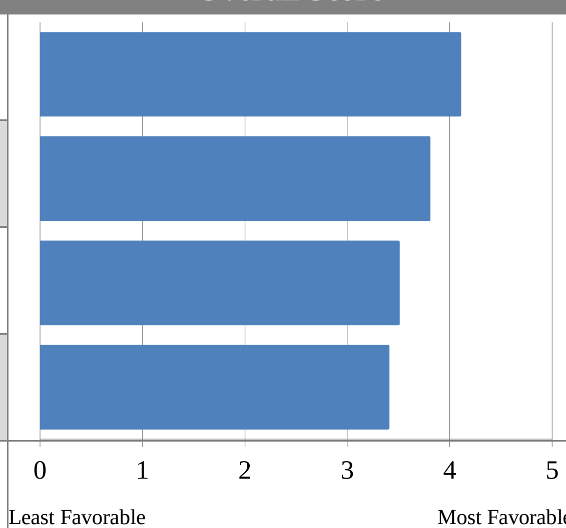
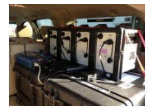


Table 4-2. Criteria Ratings

KEY

Least Favorable		→		Most Favorable
○	◔	◑	◕	●

Category	Evaluation Criterion	FlexSpec Mobile	Detective-200	Mobile Matrix ARIS	Portable Radiation Detection Kit
Capability	Gamma Detection	◕	◕	◑	◕
	Neutron Detection	◕	◕	◑	◕
	Radionuclide Identification	◕	◕	◕	◑
	Detection Sensitivity	◕	◕	◕	◕
	Field-of-View	◕	◕	◑	◕
	Position Capability	◕	◕	◕	◕
	Reachback Capability	●	◕	◕	◑
	Source Localization	◕	◑	◕	◑
	Wireless Capability	◕	◑	◑	◑
Usability	Simplicity of Operation	◕	◑	◑	◔
	Intuitive Display	●	◑	◑	◑
	Ease of Use in Moving Vehicle	◕	◑	◑	◑
	Recall Mode	◕	◕	◕	◑
	Alarms	◕	◕	◑	◕
	Misidentification Rate	◕	◕	◑	◕
	Use by Single Operator	◑	◔	◔	◔
	Spectral Information Display	◕	◑	◑	◑
Deployability	Covert Operation	◕	◕	◕	◕
	Power Source Options	◕	◕	◕	◕
	Battery Operating Time	◕	◕	◕	◕
	Vehicle Adaptability	◕	◕	◔	◕
	Equipment Size	◕	◕	◑	◔
	Environmental Specifications	●	◕	◕	◕
Maintainability	Ease of Calibration	◕	◕	◕	◕
	Modular Design	●	◕	◕	◑

Table 4-3. Key Specifications

Key Specification	FlexSpec Mobile	Detective-200	Mobile Matrix ARIS	Portable Radiation Detection Kit
Manufacturer's Suggested Retail Price	Contact vendor	Contact vendor	Contact vendor	Contact vendor
Warranty Duration	1 year; extended warranties available	1 year; extended warranties available	Information not available	1 year
Gamma Detectors*	NaI(Tl) 2 x 4 x 16 inches 4 each	HPGe 3.3-inch diameter x 1.2-inch height 4 each	NaI(Tl) Size not available 2 each Plastic scintillator 7-liter, 2 each	NaI(Tl) 2 x 4 x 16 inches 4 each
Neutron Detectors*	Lithium-6 17 x 9.5 inches 2 each	Lithium-6 2 each 40 x 11 x 5 inches (overall dimensions)	Helium-3 Size not available	Boron-10 Size information not available
Vehicle*	Chevrolet Tahoe	Vendor-rented Chevrolet Express	Chevrolet Suburban	Vendor-rented Chevrolet Suburban
Wireless Capability	Secure Wi-Fi for control and monitoring; 3G/4G cellular data transmission optional	Wi-Fi for wireless connection to computer; cellular options available	Options include cellular, satellite, 900 megahertz mobile, and mesh networking	Wi-Fi included for wireless connection to computer; cellular options available
Power Source Options	Vehicle battery; shore power with optional power supply; optional battery pack with charger	Vehicle battery; shore power with optional power supply; optional extended backup battery	Vehicle battery; shore power; backup battery	Vehicle battery; shore power; external battery
Battery Operating Time	4 hours with optional battery pack; extended battery options available	With vehicle not running, internal battery lasts 3 hours when detector is already cooled	2 hours with standard backup battery; contact vendor for other options	8 to 20 hours depending on type of wireless connectivity
Operating Temperature Range	-4°F to +131°F	+14°F to +122°F	Information not available	-4°F to +122°F
Operating Relative Humidity Range	0 to 93 percent (at 104°F)	0 to 100 percent (at 122°F)	Information not available	0 to 100 percent, non-condensing

*These specifications pertain to the assessed system. Other options are available from the vendors.

Abbreviations:
NaI(Tl) = thallium-doped sodium iodide
HPGe = high purity germanium

4.1 Bubble Technology Industries, Inc., Flex-Spec Mobile

The FlexSpec Mobile (Figure 4-1) received an overall assessment score of 4.1. The system that was evaluated was installed in a Chevrolet Tahoe and contained four thallium-doped sodium iodide (NaI(Tl)) gamma detectors, two lithium-6 neutron detectors, a control box, universal mounting kit, and a Panasonic Toughbook computer.

Figure 4-1. FlexSpec Vehicle (top) and SRD Equipment (bottom)

The following sections, broken out by SAVER category, summarize the assessment results.

<u>Capability</u>

The FlexSpec Mobile received a Capability score of 4.1. The following information is based on evaluator comments:

- The FlexSpec always detected gamma and neutron radiation when present except during some chokepoint drive-through exercises with sources that were too weak for any system to detect.
- Radionuclides were identified for all ANSI standard sources that were strong enough to alarm all four systems. Multiple radionuclides were correctly identified at several targets, and identifications were made at considerable distances from target locations. Only ANSI standard radionuclides and a few others were in the system library. However, adjustments to the library could be made easily through a spreadsheet. A radiation field guide was easily accessible through system software. Responders had the ability to consult this guide at any time to access valuable information about any radionuclide.
- Left- and right-side histograms were displayed at all times, and a colored arrow indicator giving the location of the source was displayed during alarms. The system contains an audible location indicator that increases its frequency and pitch when gamma count rate increases, but this was turned off for the assessment.
- Detection sensitivity and field-of-view met expectations. The default left/right configuration of detectors was adequate, although one evaluator commented that the field-of-view is limited in the front and back with this configuration. It is possible to orient and mount the detectors in a wide variety of configurations to increase the field-of-view, if desired.
- It is quick and easy to send data to a reachback center using system software. A form is automatically generated and auto-populated with relevant data, including spectrum files, alarm data, and user information captured at system login. All relevant data was extracted and placed on the form. With cellular communication enabled, all necessary information could be sent to a reachback center quickly and easily.

- The displays and software interface were streamed wirelessly through Wi-Fi so that the FlexSpec Mobile could be monitored and controlled with other computing devices in addition to the laptop that is included with the system. Evaluators used tablets and a wide variety of smart phones to monitor the system. All displays were available through this feature. A special application was not necessary because the FlexSpec Mobile could be operated from any computing device with an Internet browser. With this feature, operators in the backseat could see displays without leaning forward into the front of the vehicle, and the system could be operated remotely from within Wi-Fi range. Cellular service is available as an option for sending data to distant locations. Troubleshooting and repair is possible through remote wireless connection by the vendor to the system.

Usability

The FlexSpec Mobile received a Usability score of 4.2. The following information is based on evaluator comments:

- The graphical user interface (GUI) was intuitive, customizable, and easy to operate with minimal training. One evaluator commented that a lot of effort went into the software interface design.
- The displays were intuitive and pertinent information was visible to operators at all times. Left- and right-side histograms allowed operators to see frequent updates of the background radiation level, and spectral information displays were readily available. The ability to run the system from phones, tablets, and other handheld devices was a major advantage. Multiple displays could be used in the vehicle and operators in the back seat had adequate visibility. In addition, the entire system could be run from a tablet, eliminating the need for a bulky laptop that can block the dashboard and side mirrors from the driver’s field of vision. Although data was displayed clearly, one evaluator thought the yellow through red colors on the display were not easily distinguishable.
- The system performed as expected in a moving vehicle. Evaluators felt that it would be highly difficult for a single operator to drive the vehicle and operate the equipment simultaneously.
- Maps provided breadcrumb trails for the vehicle path. Although it met expectations, evaluators felt that the GPS/mapping capabilities could use an upgrade. Google Earth imagery was not available on the maps, and buildings and landscapes could not be displayed. Mapping visuals were limited to water and land mass. In addition, the breadcrumb trails were difficult to see on the map display.
- Radiation alarms were clear, had good sound quality, and provided operators with necessary information. Alarm thresholds were configurable using the radionuclide library, and other alarm features were user programmable as well. With customizable thresholds, operators could make the system more sensitive for chokepoint operations than for search mode, if desired. Multiple modes could be used for different missions. However, alarm color levels could not be configured.
- There were some radionuclide misidentifications during the search exercises. The system correctly identified the radionuclides that were present, but sometimes

included a radionuclide that was not present. Uranium-235 was identified several times when it was not actually present. Americium-241 was also reported twice when not present.

- Spectral information displayed clearly and could be accessed without going to a settings screen. Energy values were not marked clearly, which made it difficult to see if a peak was from potassium, cesium, etc.

Deployability

The FlexSpec Mobile received a Deployability score of 4.1. The following information is based on evaluator comments:

- The system was powered by the vehicle battery, which could also power the system for 4 hours after turning off the vehicle. There is a useful feature which automatically shuts down equipment when the battery voltage drops below 11.5 volts to ensure there is enough power remaining to start the vehicle. Evaluators desire a longer battery life with the vehicle not running so they can monitor covertly or remotely. For these applications, an extra battery pack that runs for 8 hours could be purchased.
- The system was designed with vehicle adaptability in mind. The assessed system was installed in a Chevrolet Tahoe, but each detector and control box was separately enclosed and transferable from one vehicle to another. Transferable systems can be installed in a variety of vehicles.
- The equipment takes up a lot of space and left little room in the Tahoe for extra equipment. If this is a concern, it can be installed in a Suburban or other larger vehicle.
- Environmental specifications were above expectations. The system could operate at wide temperature and relative humidity ranges. Detectors were waterproof, but computer cases were not.

Maintainability

The FlexSpec Mobile received a Maintainability score of 4.1. The following information is based on evaluator comments:

- Energy calibration was performed automatically, meeting the expectations of the evaluators.
- Components such as detectors and computers were relatively light (55 to 90 pounds per component) and easy to access. It is possible for two people to lift components and transfer them to another vehicle. Cables were strong and configured to be easily replaceable. Components were able to be added or repaired with minimal instruction.

4.2 ORTEC, Detective-200

The Detective-200 (Figure 4-2) received an overall assessment score of 3.8. The system that was evaluated was installed in a van rented by the vendor and contained four Detective-200 high-purity germanium detectors, a neutron-detection module consisting of two lithium-6 neutron panels, and a Panasonic Toughbook computer running Detective Remote software (version 4).

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-2. Detective-200 Vehicle (top) and SRD Equipment (bottom)

Capability

The Detective-200 received a Capability score of 4.0. The following information is based on evaluator comments:

- The system consistently detected and alerted the operator to gamma and neutron radiation when present. Good standoff detection capability was provided. High-resolution gamma spectra were produced by the germanium detectors and displayed on the screen. Evaluators considered the Detective-200 detectors to be of high quality with enhanced radionuclide identification capabilities.
- Radionuclide identification was extremely accurate, and there were no reported misidentifications. Multiple radionuclides were identified correctly in targets with more than one source. Evaluators were confident in the identifications made by the system and would recommend it for pinpoint identification over the other SRDs at the assessment. The radionuclide library was comprehensive and could be adjusted by the user. However, the radionuclide classification could not be adjusted. Uranium-235 is classified as “threat,” whereas some evaluators would like it to be called out as SNM. The system software did not contain a field guide with radionuclide descriptions.
- The system detected radiation with good sensitivity. Field-of-view was limited in the test configuration because all four detectors were on one side of the vehicle. However, the detectors are modular and can be mounted in various configurations with small adjustments. Different deployment strategies can be accommodated.
- System software provided a form for sending data to a reachback center. Operators could right-click on a spectrum file and add it to the form with ease. Once the form is configured for the agency’s use and wireless communications are established, data can be sent quickly to a reachback center in an easy and straightforward manner. Without wireless communications, data can be downloaded manually to another computing device.

- When sources were detected, a graphical detection cone was placed on the map to indicate the direction of the source. This was a convenient feature that helped operators better locate sources. An audible finder mode was available but turned off for the assessment, so operators had to keep their eyes on the screen.
- Detectors were configured to transmit data via Wi-Fi to the laptop computer. They could also be configured to transmit via USB cables. Cellular transmission is available as an option, and the laptop can be configured to transmit to remote locations.

Usability

The Detective-200 received a Usability score of 3.4. The following information is based on evaluator comments:

- System software was complex and evaluators had difficulty finding desired screens and windows. Controls were too small to click on easily. Evaluators thought that the software and controls could be made more user-friendly for first responders. Software settings do allow for simpler operating modes, but these were not tested during the assessment.
- The computer display was configurable, but difficult to understand, and the buttons and text were small. Dose rate, count rate, radionuclide identifications, alarm windows, and other important information displayed clearly and were easy to read. However, the display was too busy in its default configuration. Changes could be made, but only through an intricate menu system that was difficult to navigate. Evaluators commented that it would be nice if they could quickly change the dose rate units and add a confidence reading to radionuclide identifications.
- Operation in a moving vehicle would be easier if the tabs, buttons, and fonts were made larger. Evaluators thought it would be difficult and/or unsafe to drive the vehicle without a partner to operate the system.
- GPS mapping was provided with a breadcrumb trail for the vehicle path. Previous detection events were saved, and detection cones appeared on the maps to indicate the direction of sources. However, signal acquisition time was a little long, and the map tended to lag behind the actual vehicle position. The map did not orient to the vehicle when turns were made. Evaluators felt that a better mapping display and mapping profile could be installed.
- Alarm settings and configurations were customizable in a straightforward manner. Thresholds could be set easily, and various colors could be used for the different alarm types. Visual alarms were clear and contained all necessary information. The audible alarm feature was disabled for much of the assessment and was not observed by some evaluators.
- No radionuclide misidentifications were observed by evaluators during the assessment.
- Gamma-spectrum displays were available through a vendor-specific application that was installed on the laptop. Peaks could be distinguished with very high resolution. The gamma energy and units were not displayed or were difficult to see.

Deployability

The Detective-200 received a Deployability score of 4.2. The following information is based on evaluator comments:

- The germanium detectors need to be kept cool or they will be unavailable until a cooling cycle is completed. The units run from vehicle power, but operating time on the supplied backup battery is 3 hours. This is insufficient to keep the system cool overnight when the vehicle is not running. A backup power supply and heftier backup battery can be purchased. Evaluators consider these essential for satisfactory deployability.
- Transferring detectors to another vehicle appeared to be relatively easy. Emergency responders can configure the system in any manner desired, and the detectors can be placed on trucks, boats, forklifts, and many other platforms.
- Detectors are relatively small and allow for extra room in the vehicle. The aluminum brackets used during the assessment took up a lot of space, but could be replaced by smaller brackets.

Maintainability

The Detective-200 received a Maintainability score of 3.9. The following information is based on evaluator comments:

- Energy calibration was performed automatically.
- The Detective-200 units and neutron panel make up a compact, light-weight modular system that can be mounted in many different configurations to accommodate different detection needs.

4.3 Thermo Scientific, Inc., Mobile Matrix ARIS

The Mobile Matrix ARIS (Figure 4-3) received an overall assessment score of 3.5.

The system that was evaluated was installed in a Chevrolet Suburban and contained two 7-liter plastic scintillators with natural background rejection technology, two sodium iodide detectors, one helium-3 neutron detector, control hardware, and a Panasonic Toughbook computer. The system tested belonged to a participating police agency and was approximately 3 years old.

Figure 4-3. Mobile Matrix ARIS Vehicle (top) and SRD Equipment (bottom)

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The Mobile Matrix ARIS received a Capability score of 3.5. The following information is based on evaluator comments:

- Gamma radiation was consistently detected with good sensitivity. Dose rate and counts per second readings were displayed clearly. Detectors had flashing lights that allowed operators to see some results without looking at the display screen. The vendor's proprietary gamma-spectrum viewer did not produce quality spectrum displays.

- Neutrons were consistently detected with suitable alarms and messages with the exception that one evaluator did not observe a neutron alarm for target area 10 on the large-area search. Neutron alarms were audibly clear, but visually could get lost in the cascade of alarms on the screen. The neutron display screen, although small, was able to be manipulated to view in a larger scale.

- Although radionuclide identification met expectations, radionuclides were not always identified correctly, and there were many misidentifications. System software did not provide a field guide or reference library for radionuclides in which responders could look up information while in the vehicle. Operators were not able to add radionuclides or adjust the radionuclide library manually. The vendor has to be notified in order to make changes.

- Detection sensitivity was very good with the instrument responding to distant sources. The natural background rejection technology increased sensitivity and gave confidence in alarm readings. Evaluators felt that the instrument has more than adequate sensitivity for first-responder applications.

- The detection field-of-view was adequate, but the system components were heavy and not moveable and could not be arranged to increase field-of-view.

- Data could be downloaded to a thumb drive and sent to a reachback center from an external computing device. There were no features in the software to facilitate the process and no direct link to a reachback center from within the system software.
- There was a visual graph for left- and right-side detectors. However, there were no directional indicators on the map to determine source direction and there was no audible finder mode with changing tones to indicate source strength.
- The system contains Viewpoint software, which is useful for connection to an external command center. Multiple devices can be monitored at the command center with Viewpoint. The system tested was not configured with wireless communications, but it is available as an option.

Usability

The Mobile Matrix ARIS received a Usability score of 3.2. The following information is based on evaluator comments:

- The user interface was complicated and took time to learn how to use. There was a lot of information on the screen, but this made the display busy and confusing. The data was often difficult to read and interpret, and it was difficult to make adjustments and find the right controls. Buttons were small, making the system difficult to control. Evaluators felt that a more user-friendly design is needed to make it easier to learn and operate.
- Dose rate, count rate, and radionuclide identification indicators were clear and easy to read. However, the display had low resolution, poor color contrast, and the font was difficult to read. Cascading alarm windows pop up rapidly on the screen and can cause the operator to lose an alarm as the windows drift off the screen. An event log was displayed, but it was small and difficult to see. One evaluator suggested reorganizing the display to focus on the map and allow operators to drill down for more information as needed.
- There were no difficulties operating the system with the vehicle in motion. However, a second operator is needed due to the complexity of controls and difficulty in reading the display screen.
- Mapping and recall features had above-average quality and time-stamping features were good. The map leaves bells in the locations that were visited so that operators can drive back to selected locations. Alarms are captured on the map and the operator can recall previous alarms through the map display. There was room for improvement in mapping details.
- Alarms were clear on the display and through audible alerts and voice messages. Alarm settings were highly customizable. Operators could add custom settings, custom alarm sounds, and a custom alarm priority list. Voice messages could be programmed to be concise or verbose. Popup alerts were displayed on screen for radionuclides of interest. The radionuclide library could not be adjusted, however.
- There were a large number of radionuclide misidentifications during the search exercises. When radionuclides that were present were identified correctly, there would often be one or more identified radionuclides that were not present. One evaluator

commented that with so many radionuclides identified incorrectly, it is difficult to have much confidence in any identification.

- The spectrum display could only be viewed when there was an alarm. Spectrum resolution and display were low quality, and gamma-energy indicators were not present on the horizontal axis.

Deployability

The Mobile Matrix ARIS received a Deployability score of 3.7. The following information is based on evaluator comments:

- The system operates from the vehicle battery. An external plug is provided for shore power, and a backup battery system is in place that will operate equipment for 2 hours when the vehicle is shut off.
- The equipment is heavy and not easily transferrable to another vehicle; a forklift or other mechanical means would be needed. The system is custom built into a Chevrolet Suburban and would require great effort to move into another vehicle. The design is not modular. One evaluator commented that the size and weight of the system causes undue stress on vehicle suspension and cooling systems.
- There is a fairly large amount of storage space in the back of the vehicle, allowing extra equipment to be carried.

Maintainability

The Mobile Matrix ARIS received a Maintainability score of 4.2. The following information is based on evaluator comments:

- The system self-calibrates upon system startup.
- Detectors have a modular design, but other system components are not modular, and none of the equipment can be easily moved.

4.4 Nucsafe, Inc., Portable Radiation Detection Kit

The Portable Radiation Detection Kit (Figure 4-4) received an overall assessment score of 3.4. The system that was evaluated was installed in a Chevrolet Suburban rented by the vendor and contained four sodium iodide gamma detectors, a boron-10 neutron detector, control module, and a laptop computer running Mobile Mission control software.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-4. Portable Radiation Detection Kit Vehicle (top) and SRD Equipment (bottom)

<u>Capability</u>

The Portable Radiation Detection Kit received a Capability score of 3.5. The following information is based on evaluator comments:

- The system was proficient at detecting gamma radiation at distances well away from the source. However, there was a slight lag in detector response time.
- After not detecting neutrons for the first rotation, a software configuration error was discovered and the system did well detecting neutrons in subsequent exercises. Neutron alarms were displayed in blue to distinguish them from gamma alarms, but this made them seem like less of a priority to some evaluators. Neutron alarms were not categorized as a threat. Neutron counts increased without alarming on some exercises, and the threshold could not be quickly adjusted.
- Radionuclide identification met expectations despite not always identifying the correct radionuclide. The radionuclide library was not comprehensive, and although it was customizable, it was a complicated process to add radionuclides using system software. There was no option to categorize or color code radionuclides, and some radionuclides were categorized in a way that was not agreeable to evaluators. For instance, cesium-137 was listed as medical[3] instead of industrial.
- Gamma and neutron detectors were of sufficient size and area to allow for high sensitivity. The modular detector cases made the system highly customizable with different detector arrangements easily attainable. The assessment configuration had a wide field-of-view.

[3] Although not given orally or injected into patients, some of the uses of cesium-137 are medical in nature.

- There were no built-in reachback capabilities in the software, and data had to be extracted from multiple locations on the file system in order to perform a reachback operation. Information should be contained in a single folder for ease of data transfer.
- Red arrows were displayed on the map to indicate the direction from which gamma radiation was coming, giving a visual display of source location. Although evaluators liked this feature, they would have preferred an audible finder mode with pitch or tone change according to the proximity of the source.

Usability

The Portable Radiation Detection Kit received a Usability score of 3.1. The following information is based on evaluator comments:

- System software was overly complicated and not easily operated. Adjustments to settings required navigating a confusing assortment of screens with many layers. The user interface was not intuitive and would require much training in order for users to become proficient.
- The display contained most of the information needed by the operator, and color brightness and contrast were good. However, the screens were not well organized and important information such as dose rate and neutron counts were displayed with small fonts and were difficult to find. Too much information was displayed, making font and button sizes too small. A more user friendly design is needed in which essential information is displayed and highlighted with simple controls, allowing for more detailed information to be brought up as needed.
- The display and controls were too complex to be used by a single operator. Operation in a moving vehicle was difficult due to small fonts and button sizes. Information was there, but difficult to see.
- The mapping display and performance of the GPS system was good. Breadcrumbs were painted on the display with colors to indicate radiation level, and the entire mission could be recalled easily. Maps were very detailed with sophisticated satellite imagery, and there was no noticeable lag in vehicle position. Pre-loaded maps were available as a backup in case GPS satellites are not working. An orientation indicator such as a vehicle icon was lacking.
- Gamma alarms were clearly announced, but the radionuclide identification was not obvious. Neutron alarms could have been more accentuated. Alarm settings and thresholds were highly customizable, but it was somewhat difficult to navigate the settings screens.
- There were very few misidentifications of radionuclides.
- The spectrum display was of good quality and resolution, but spectra could not be easily displayed. There should be a simple command to call up spectra, or spectra should automatically display during alarms. A waterfall display was also included, but was of very poor quality.

Deployability

The Portable Radiation Detection Kit received a Deployability score of 3.8. The following information is based on evaluator comments:

- The system can operate using the vehicle battery, and it comes with an external battery that can power the system for 8 to 20 hours, which is more than adequate for emergency responders. Evaluators suggested having an internal battery indicator in the software and standard power connectors (plugs).
- The light weight of components and modular system design with Pelican cases makes the system easy to deploy in many different vehicle types.
- The assessed configuration takes most of the room in a Chevrolet Suburban with little room left for extra equipment.

Maintainability

The Portable Radiation Detection Kit received a Maintainability score of 3.6. The following information is based on evaluator comments:

- The system automatically calibrates on potassium-40 in the background. However, background acquisition takes several minutes, and the system needed to re-establish background several times during the assessment, reducing time for the mission.
- A highly modular system design allows many different types and sizes of detectors to be installed, including backpacks and cases that will fit in the trunk of a car.

5. SUMMARY

SRDs are valuable tools that can be used by law enforcement and emergency response personnel to find lost or missing radiation sources, interdict illicit radiological material, and keep the public safe from the threat of radiological and nuclear terrorism. All assessed SRDs detected gamma and neutron radiation with adequate sensitivity, performed energy calibration automatically, and were consistent with covert operation. There were significant differences in the performance of other features such as radionuclide identification, source localization, mapping, reachback capability, and wireless capabilities.

Evaluators stressed the need for user-friendliness and simplicity of operation in emergency response scenarios. Advanced features and complex data screens are useful as long as the main user interface is intuitive, easy to operate, and easy to read. System software should be flexible enough so that it can be configured for both health physicists and for patrol officers.

The advantages and disadvantages for the assessed products are highlighted in Table 5-1.

Emergency responder agencies that consider purchasing SRDs should carefully research each product’s overall capabilities and limitations in relation to their agency’s operational needs.

Table 5-1. Product Advantages and Disadvantages

Vendor/Product	Advantages	Disadvantages
 Bubble Technology Industries, Inc. FlexSpec Mobile Overall Score: 4.1	• Display and controls available on smart phones and tablets via Wi-Fi • Reachback form with automatic data extraction • Radiation Field Guide included in software • Simple and intuitive display and controls • Clear, customizable alarms • High vehicle adaptability	• Limited map visuals • Breadcrumb trail was difficult to see
 ORTEC Detective-200 Overall Score: 3.8	• Very accurate radionuclide identification • Sensitive detectors • Reachback form with automatic data extraction • Source location cones on map display • Light-weight, modular, and rugged detectors	• Small text and buttons on software • Germanium detectors need to be kept cooled, which requires constant power
 Thermo Scientific, Inc. Mobile Matrix ARIS Overall Score: 3.5	• Sensitive detectors • Natural background rejection technology • Customizable alarms with audio • Extra storage space	• High rate of misidentifications • Complicated software and controls • Heavy equipment • Non-modular design
 Nucsafe, Inc. Portable Radiation Detection Kit Overall Score: 3.4	• Sensitive detectors • Few misidentifications • Quality mapping capability with sophisticated imagery • Arrow indicators for source location • Modular design • Long battery life	• Slight lag in detector response time • Background had to be re-acquired at times • Difficult to export data for reachback • Overly complicated software for emergency responders

APPENDIX A. EVALUATION CRITERIA DEFINITIONS

The focus group identified 49 evaluation criteria, which are defined as follows.

CAPABILITY

Gamma Detection refers to the overall capability of the system to detect and measure the energy of gamma rays. This category includes features such as the number of gamma detectors, their type, size, range, and efficiency, as well as the resolution and quality of gamma spectra produced by the system. Focus group participants consider gamma detection an essential function of an SRD.

Neutron Detection refers to the overall capability of the system to detect neutrons emitted from a radiological source. This category includes features such as the number of neutron detectors, their type, size, efficiency, and susceptibility to interference from gamma rays. It also includes the type and amount of moderation material used to slow down fast neutrons in order to permit detection. While neutron detection is often considered an optional feature in radiation detection systems, the focus group felt that it is an essential function of an SRD.

Radionuclide Identification refers to the ability of the system to correctly identify the radionuclide(s) of the radioactive material causing the alarm. Focus group participants indicated that the system software should contain a comprehensive and customizable library of radionuclides and categorize each identified radionuclide as industrial, medical, natural, or special nuclear material. Radionuclide identification was considered an essential feature.

Detection Sensitivity refers to the ability to detect a small radiation signal from a radioactive source. Detector size and efficiency are the major factors affecting detection sensitivity. A detector with large volume and high efficiency will collect more counts from a remote source compared with a smaller or less efficient detector. Focus group participants did not recommend a specific sensitivity, but indicated that it is important to have an appropriate sensitivity for the intended application.

Field-of-View refers to the angular range viewed by the detector within which a source can be detected in both the vertical and horizontal planes. A 360-degree horizontal field-of-view would allow detection of a source placed at any angle from the front of the SRD vehicle. A wide vertical field-of-view would allow a source to be detected at a high angle of elevation. Focus group participants felt that vertical field-of-view is just as important as horizontal field-of-view. They preferred at least a 45-degree vertical field-of-view.

Position Capability refers to the ability to determine the latitude and longitude of the SRD vehicle through use of either a global positioning system (GPS) receiver or a similar technology. Focus group participants wanted the ability to save and recall radiation data with position information.

Reachback Capability refers to features that allow the system operator to send spectral files to another location for analysis. Since radionuclide identification by software is never foolproof and can give uncertain results, focus group participants want SRD systems to have an easy method for sending data to a reachback facility for further analysis. It can involve sending the files by wireless or offloading to a laptop with wireless capability. Participants prefer a software feature or utility that automatically captures the latest background and calibration files and sends them with the unknown spectrum.

Source Localization refers to the ability of the system to assist in determining the direction of the radioactive source. Focus group participants expect something better than just right- or left-side indicators. Possible methods for doing this include imaging, detector arrays, and a finder mode with audible high-pitched chirping for higher readings.

Wireless Capability refers to the ability of the system to transmit data to a remote computer through an appropriate wireless technology such as Bluetooth or Wi-Fi (IEEE 802.11).

Remote Paging refers to the capability of transmitting alarms to a separate handheld unit. This should be implemented as an optional feature with the ability to turn on and off.

Command Center Connectivity refers to the capability of connecting and exchanging data with the agency command and control center. This should be implemented as an optional feature with the ability to turn on and off.

Environmental Mode Capability refers to the system having modes for operating in different environments such as urban, rural, and marine. In systems with this capability, each mode uses a separate algorithm to interpret current and background radiation levels and determine if there should be an alarm. Focus group participants felt that this is important because their experience shows that a single algorithm does not work effectively in all environments.

Imaging Capability refers to the ability of the system to produce an image that indicates the location and intensity of the source. Imaging may also allow detection of a source that produces an exposure rate less than the background level. Imaging capability was not available on any of the assessed products.

USABILITY

Simplicity of Operation refers to the ability to operate the system easily, without confusion, and with minimal training. Focus group participants considered this to be an essential feature.

Intuitive Display refers to having system data such as radiation exposure rates, alarms, spectra, and radionuclides displayed in a clear and intuitive manner. Focus group participants pointed out that screen location, screen resolution, and quality of system software are major factors in an intuitive display.

Ease of Use in Moving Vehicle refers to the ease of operating the system in a moving vehicle where factors such as bumps, vibrations, accelerations, and road noises are present.

Recall Mode refers to the ability of the system to play back stored radiation data linked to location and time. Focus group participants want the ability to map radiation levels and have the data available for later use.

Alarms refers to the overall quality and clarity of radiation-related alarms produced by the system. Focus group participants want both audible and visible alarms and the ability to toggle either type on and off. They also indicated the importance of having flexible settings for controlling how alarms are triggered.

Misidentification Rate refers to the percentage of alarms in which the system mistakenly identifies a radionuclide that is not present. Focus group participants noted the importance of having a low misidentification rate due to the time and effort required to investigate such incidents.

Use by Single Operator refers to whether or not the system can be operated by a single operator. Some vehicle-mounted detection systems require two or more operators.

Spectral Information Display refers to the ability to display gamma spectra. Some systems consider gamma spectra to be extraneous information that may just confuse the user, but the focus group participants want to be able to see it.

Training Mode refers to a system feature in which the software simulates sources and alarms for training purposes. Since most emergency response organizations do not have access to all the threatening materials that they may need to locate, the focus group participants stated that they want a training mode that can display all the indicators and alarms that would occur should such materials be detected.

Computer Compatibility refers to whether or not the system software can operate on and/or communicate with other computer systems such as a laptop computer.

DEPLOYABILITY

Covert Operation refers to the ability of the system to perform its functions in a manner in which no one but the operators will know that it is scanning for radioactive material. This was considered to be an essential feature by the focus group.

Power Source Options refers to the various means by which the system can be powered. These may include vehicle battery, standalone battery, generator, shore power, and backup battery. Focus group participants want the system to be able to operate with multiple power sources.

Battery Operating Time refers to the amount of time the system can operate on battery power if that is the sole power source. Participants would not consider buying a battery-operated device that did not operate for at least 12 hours if that were the only power source.

Vehicle Adaptability refers to the ability of the system to operate in different vehicles and vehicle types and the ease with which it can be transferred. For systems that include a vehicle, participants preferred equipment that is mounted on a removable tray so that it can be transferred to another similar vehicle.

Equipment Size refers to the size of equipment relative to the vehicle in which the SRD is mounted. Participants want the equipment size to be appropriate for the application and to have additional capacity in the vehicle to allow for carrying extra equipment.

Ruggedness refers to the ability to withstand harsh operating environments and vehicular conditions such as bumpy roads, turbulence, vibrations, and sudden acceleration and deceleration. Focus group participants stated that the detectors and related equipment must be resistant to vibration, in particular.

Environmental Specifications refers to operating temperature, operating relative humidity, waterproofing, dust-proofing, etc. Focus group participants felt that the specification must be appropriate for the operating environment, e.g., equipment placed on boats must be waterproof; equipment used outside of the temperature-controlled environment of a vehicle must have a wide operating temperature range.

Connector Quality refers to the specifications and overall quality of the physical connectors in the wiring system. Focus group participants have experienced substantial costs and loss of

equipment time due to needed repairs caused by damaged connectors. They feel that high-quality connectors that meet military specifications should always be used.

Resistance to RF Interference refers to the ability of the system to withstand radio frequency interference. First responders use many different radios and wireless communication systems. Many of the focus group participants have experienced radio interference with electronic equipment and, therefore, are highly concerned about RF interference.

Temperature Stability refers to a gamma or neutron detector's ability to maintain a stable reading when moving from a hot to a cold environment, and vice versa.

MAINTAINABILITY

Legally Defensible Data refers to whether or not the vendor provides equipment, software, and calibration services such that radiation measurements from the system are presentable in a court of law.

Frequency of Repair or Service refers to the number of times per year that the equipment needs to be serviced or repaired by the vendor. This includes routine maintenance service.

Quality of Customer Support refers to the overall quality of customer support provided by the vendor. Factors influencing quality of customer support include the ability to quickly speak with support personnel, getting answers to technical questions, and help in troubleshooting the system.

Amount of Downtime refers to the amount of time that the system is unavailable due to needed repairs or routine service.

Ease of Calibration refers to the availability and ease of use of a test routine built into the equipment that allows the operator to place a test source in the vicinity of the detectors and ensure proper energy calibration and operation of the system.

Ease of Troubleshooting refers to the ability of operators to determine the cause of problems encountered with the equipment. This is important to the focus group participants because identifying the problem often allows them to avoid substantial expense and downtime involved with returning the equipment to the vendor for repair.

Modular Design refers to the ability to easily add, remove, and replace components of the system, especially detectors. Focus group participants want SRD systems to allow for additional and different sized detectors.

Time that Vendor Supports Model refers to the period of time that the vendor will support the particular model with service, repairs, and customer support. Focus group participants have experienced buying equipment and then having the vendor discontinue support for the model after a short time.

Service Location Flexibility refers to flexibility on the part of the vendor as to where the equipment will be repaired. Some vendors require shipping the equipment to their repair facility. Focus group participants want the option of having the vendor send a repair technician to their facility.

Software Updates refers to the availability and ease of installation of software updates to the system.

AFFORDABILITY

Initial Cost refers to the up-front purchasing cost of the system and all necessary accessories. The system may or may not include a vehicle. If it does not include a vehicle, it should include all necessary parts and accessories for mounting the equipment in a separately purchased vehicle. Focus group participants indicated that due to budget pressures, SRD systems must have an affordable and competitive initial cost.

Maintenance Cost refers to the accumulated costs involved with keeping the purchased equipment at operational status. This includes routine maintenance of the vehicle if purchased, detector calibration, software upgrades, etc. It also includes technician travel for maintenance purposes, which, according to the focus group, can involve high costs.

Terms of Service Contract refers to the availability of an appropriate service contract that will allow emergency response organizations to maintain the equipment while minimizing ongoing expenses. Focus group participants stated that they prefer a long-term contract which covers parts, labor, and calibration. They stressed the importance of being able to pay for a service contract up front with grant money because they have very limited annual budgets for equipment maintenance.

Training Cost refers to the accumulated costs associated with training operators to use the equipment.

Repair Cost refers to the accumulated costs associated with making repairs to the equipment including replacement parts, labor, technician travel, and shipping to a repair facility. Focus group participants noted the importance of the location of the repair facility in keeping repair cost low, as some vendors will only make repairs at their own facility, which may be across the country or overseas.

Trade-in Value/Disposal Options refers to the ease of disposing of the equipment and the amount of money that can be recouped after its life cycle has ended. Focus group participants noted that detection vehicles are often difficult to dispose of and that vendors should provide disposal options.

APPENDIX B. SCORING FACTORS CONSIDERED BY EVALUATORS

Evaluators were given a score sheet for each product containing the following scoring factors that were to be considered in assigning a score to each criterion.

Criterion	Considerations
Gamma Detection	The SRD consistently detected gamma radiation when present, displayed the dose (or exposure) rate in clear and appropriate units, performed auto-ranging, and produced a high-quality gamma spectrum.
Neutron Detection	The SRD consistently detected neutron radiation when present, alerted the operator to the presence of neutrons, and displayed the neutron count rate.
Radionuclide Identification	• The SRD consistently and correctly identified the radionuclide(s) present in gamma-radiation sources. • Radionuclides that were identified by the system were categorized in a way that helped to determine their threat level, such as "industrial, medical, natural, or special nuclear material." • The SRD contains a library of radionuclides that meets my agency's needs or can be customized to meet my agency's needs.
Detection Sensitivity	• Based on performance observations and the number, size, and type of gamma detectors, the gamma-detection sensitivity of the SRD is adequate for my agency's needs. • Based on performance observations and the number, size, and type of neutron detectors, the neutron-detection sensitivity of the SRD is adequate for my agency's needs.
Field-of-View	The SRD can detect sources with a wide field-of-view, or the detectors can be easily arranged so that they can detect radiation sources with a wide field-of-view.
Position Capability	The ability of the SRD to measure, store, and display its latitude and longitude is adequate for my agency's needs.
Reachback Capability	• It is an easy and straightforward process to download data from the SRD to an external computing device. • The SRD software contains features that facilitate sending gamma spectroscopic data to a reachback center.
Source Localization	The SRD contains features (detection zones, audible finder mode, etc.) that allow operators to effectively locate a radiation source.
Wireless Capability	The ability of the SRD to transmit data wirelessly to a remote computer is adequate for my agency's needs.
Simplicity of Operation	The SRD software and controls could be operated easily, without confusion, and with minimal training.
Intuitive Display	• The resolution and location of display screens were adequate for my agency's needs. • System data, such as radiation exposure rates, alarms, spectra, and radionuclides, were displayed in a clear and intuitive manner. • The display of the radiation dose rate (or exposure rate) measurement with its measurement units is adequate for my agency's needs.

Ease of Use in Moving Vehicle	The SRD could be easily operated while the vehicle was moving and experiencing factors such as bumps, vibrations, accelerations, and road noises.
Recall Mode	• The ability of the SRD to store radiation data linked to time and position is adequate for my agency's needs. • The ability of software provided by the vendor to play back stored radiation data linked to time and position is adequate for my agency's needs.
Alarms	• The overall quality and clarity of radiation-related alarms produced by the SRD were adequate for my agency's needs. • Alarm types and settings were customizable and easy to set with system software.
Misidentification Rate	The number of times that the system alarmed when radiation was not present or identified a radionuclide that was not present was minimal.
Use by Single Operator	The SRD system can be effectively operated by a single operator while driving.
Spectral Information Display	Gamma spectra can be displayed during operation, and the spectrum display and resolution are adequate.
Covert Operation	The SRD was able to perform its functions in such a way that only the operators were aware that it was scanning for radiation.
Power Source Options	Options for powering the SRD equipment (vehicle battery, AC power, battery, etc.) are adequate for my agency's needs.
Battery Operating Time	If a non-vehicle battery is the sole power source, the amount of time that the system can operate on such power is adequate for my agency's needs.
Vehicle Adaptability	The SRD system can operate in different vehicles and can be easily transferred between vehicles. (For systems that come installed in a vehicle, a removable tray or other features allow for vehicle adaptability.)
Equipment Size	The size of equipment installed in the vehicle is appropriate to my agency's needs and allows for additional room in the vehicle for carrying extra equipment.
Environmental Specifications	The temperature and relative humidity specifications for the SRD are appropriate for its anticipated operating environment and adequate for my agency's needs.
Ease of Calibration	The SRD system did not require a daily energy calibration or could easily be calibrated with a check source.
Modular Design	The design of the system was such that detectors, computers, and other components could easily be added, removed, or replaced.

APPENDIX C. ASSESSMENT SCORING FORMULAS

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.

Category Score Formula

$$\frac{\sum\left(\mathit{Average\ Criterion\ Rating} \times \mathit{Criterion\ Weight}\right)}{\sum\left(\mathit{Criterion\ Weights}\right)} = \mathit{Category\ Score}$$

Category Score Example[4]

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

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.

Overall Score Formula

$$\sum\left(\mathit{Category\ Score} \times \mathit{Category\ Percentage}\right) = \mathit{Overall\ Assessment\ Score}$$

Overall Score Example[1]

$$\underbrace{(4.0 \times 33\%)}_{\mathit{Capability}} + \underbrace{(4.2 \times 27\%)}_{\mathit{Usability}} + \underbrace{(4.2 \times 20\%)}_{\mathit{Affordability}} + \underbrace{(3.8 \times 10\%)}_{\mathit{Maintainability}} + \underbrace{(4.5 \times 10\%)}_{\mathit{Deployability}} = 4.1$$

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