



Handheld Raman Spectrometers

Assessment Report

November 2023



Science and
Technology





The “Handheld Raman Spectrometers Assessment Report” was prepared by the National Urban Security Technology Laboratory – in conjunction with the Pacific Northwest National Laboratory – for the U.S. Department of Homeland Security, Science and Technology Directorate pursuant to Interagency Agreement 7ORSAT18KPM000187/P00001.

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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. In conjunction with the Pacific Northwest National Laboratory, NUSTL conducted an assessment of commercially available handheld Raman spectrometers. This equipment falls under AEL reference numbers 07CD-01-DPRS titled Detector, “Raman Spectroscopy, Point,” 07ED-01-LASR titled “Detector, Explosive, Laser-Based,” and 07ED-04-LASR titled “Detector, Explosive, Laser-Based, Standoff.”

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

Handheld Raman spectrometers are rugged, field-portable instruments that provide emergency responders with the ability to analyze unknown powders and liquids without destroying the sample during hazardous materials (“hazmat”) operations. Handheld Raman spectrometers may be used to perform direct sampling of a loose solid or liquid material or to conduct sampling on containerized material. Common applications include identification of illicit drugs or drug production precursors, explosives or explosive production precursors, industrial chemicals, or common household materials. Handheld Raman spectrometers fall under AEL reference numbers 07CD-01-DPRS titled “Detector, Raman Spectroscopy, Point,” 07ED-01-LASR titled “Detector, Explosive, Laser-Based,” and 07ED-04-LASR titled “Detector, Explosive, Laser-Based, Standoff.”

In April 2022 the National Urban Security Technology Laboratory’s (NUSTL) System Assessment and Validation for Emergency Responders (SAVER) program conducted an operational assessment of ten commercially available handheld Raman spectrometers. The assessment took place at NUSTL in New York, New York.

Six hazmat response subject matter experts from various jurisdictions with at least five years of experience using handheld Raman spectrometers served as evaluators. Evaluators assessed ten different products according to specifications and through operational use.

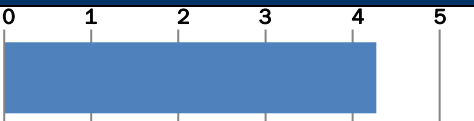









Evaluators concluded that three handheld Raman spectrometers met all their expectations, five met most of their expectations and two met some of their expectations. Overall scores ranged from 2.8–4.3 (on a scale of 1–5). The table below presents the overall scores as well as the category scores for each product. Additionally, prior to the operational assessment, the Pacific Northwest National Laboratory (PNNL) conducted laboratory testing of the devices, including scanning a number of samples in various containers. The limited distribution test report can be provided to federal, state, local, tribal and territorial responders only, upon request by emailing NUSTL@hq.dhs.gov.

The purpose of this assessment report is to provide emergency responders with information that will guide their agencies in making operational and procurement decisions. Emergency responder agencies should consider overall capabilities, technical specifications, and limitations of handheld Raman spectrometers in relation to their agency’s operational needs when making equipment selections.

Assessment Results

The table below presents the overall scores as well as the category scores for each handheld Raman spectrometer. The products are ordered by overall score from high to low.

Overall Scores Summary Table

Product	Overall Score	Overall*	Capability	Usability	Deployability	Maintainability
Agilent-Resolve		4.3	4.5	4.4	4.2	3.7
Thermo Scientific-Gemini		4.2	4.3	4.4	3.9	3.7
Thermo Scientific-First Defender RMX		4.0	4.0	4.2	4.1	3.8
Rigaku-ResQ CQL		3.9	4.1	4.1	3.6	3.7
B&W-TacticID-1064 ST		3.8	3.8	4.2	3.8	3.4
Metrohm-Mira DS		3.5	3.5	3.7	3.5	3.3
Smiths Detection-ACE-ID		3.0	2.6	3.3	3.2	3.6
Serstech-Arx		3.0	2.5	3.1	3.2	3.9
Pendar-X10		2.9	3.1	2.9	2.4	3.1
Chemring-PGR-1064		2.8	2.4	2.7	3.3	3.5

Scoring key: 1 (least favorable) to 5 (most favorable)
 Overall score is a weighted average of the category scores. See section 2.0 for category weights.



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1.0 INTRODUCTION

From April 25 to April 29, 2022, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operational assessment of handheld Raman spectrometers at the National Urban Security and Technology Laboratory (NUSTL) in New York, New York. The purpose of this assessment was to obtain information on handheld Raman spectrometers for use in hazardous materials (“hazmat”) operations, which can be used by those making operational and procurement decisions. Assessment activities were based on recommendations from a focus group of subject matter experts with experience using handheld Raman spectrometers for hazmat operations that was conducted in February 2020.¹

Prior to the assessment, the Pacific Northwest National Laboratory (PNNL) conducted laboratory tests on 12 instruments to obtain data used to facilitate designing this assessment.² The testing included determining each spectrometer’s ability to identify:

- substances within different types of containers that responders often encounter
- samples containing one or more chemical compounds
- fluorescent samples
- substances with different properties (e.g., solids, liquids)

The laboratory tests informed the selection of sample materials and containers that SAVER provided to the responder evaluators during the operational assessment. PNNL also tested performance of the reachback support provided by instrument manufacturers who offer that service. The PNNL test results are captured in a limited distribution report that can be provided upon request to federal, state, local, tribal, and territorial responders only, by emailing NUSTL@hq.dhs.gov.

1.1 Participant Information

Six first responders assessed handheld Raman spectrometers following procedures developed by NUSTL and PNNL. Evaluators were selected for the assessment based on their respective geographic location and operational experience using handheld Raman spectrometers during hazmat operations. Each participant’s professional information is listed in Table 1-1.

Table 1-1 Evaluators’ Professional Backgrounds

Evaluator Discipline	Years of Experience	State
Firefighter/HAZMAT	20+	WA
Firefighter/HAZMAT	20+	FL
Firefighter/HAZMAT	15-20	DC
Firefighter/HAZMAT	10-15	CA
Firefighter/HAZMAT	5-10	MD
Law Enforcement/HAZMAT	5-10	NJ

¹ The “Handheld Raman Spectrometers Focus Group Report” can be found in the SAVER Document Library at www.dhs.gov/publication/handheld-raman-spectrometers.

² The instruments included in this report are also in the lab report with the exception of the Serstech Arx. Additional instruments that underwent laboratory testing were the Anton Paar Cora 100, Bruker Bravo and Field Forensics HandyRam II.

1.2 Assessed Products

Ten handheld Raman spectrometers were selected for the assessment based on market research and focus group recommendations. The focus group considered their familiarity with products and those that were manufacturer-recommended models for hazmat responses. Participants also recommended comparing products with different features and laser excitation wavelengths. The 10 products³ included in the assessment are shown in Table 1-2:

Table 1-2 Assessed Products' Key Specifications

Vendor	Product	Product Image
Agilent	Resolve	
B&W	TacticID-1064	
Chemring	PGR-1064	
Metrohm	Mira DS	
Pendar	X10	

³ Focus group recommendations included 12 products. Products using hardware from the same original equipment manufacturer were not included, and one manufacturer declined to participate in the SAVER assessment.



Vendor	Product	Product Image
Rigaku	CQL	
Arx	Serstech	
Smiths Detection	ACE-ID	
Thermo Scientific	First Defender RMX	
Thermo Scientific	Gemini	



2.0 EVALUATION CRITERIA

The SAVER focus group on handheld Raman spectrometers identified 20 evaluation criteria and assigned each criterion to one of the five established SAVER assessment categories described below.

- **Affordability** criteria relate to the total cost of ownership over the life of the product, including 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 or 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

The focus group participants assigned weights indicating the level of importance of each evaluation criterion and of the five SAVER assessment categories. Evaluation criteria were weighted on a 1 to 5 numerical scale, with 1 indicating that an evaluation criterion is of minor importance and a 5 indicating that an evaluation criterion is of utmost importance.

The SAVER assessment categories were then assigned a percentage to represent each category's importance relative to the other categories. Note that the Affordability category was not considered in this assessment; the focus group decided not to weight the affordability criteria category because affordability greatly varies based on an emergency department's budget. Table 2-1 presents the evaluation criteria and their associated weights as well as the percentages assigned to the SAVER categories. Definitions of the evaluation criteria are available in Appendix A.

Table 2-1 Evaluation Criteria

SAVER Categories			
Capability	Usability	Deployability	Maintainability
Overall Weight 40%	Overall Weight 30%	Overall Weight 20%	Overall Weight 10%
Evaluation Criteria			
Library Weight: 5	Spectrum Analysis Tools Weight: 5	Durability Weight: 5	Calibration Requirements Weight: 4
Measurement Capabilities Weight: 5	Ease of Use Weight: 5	Decontamination Weight: 4	Consumables Weight: 3
Sample Identification Through Containers Weight: 5	Functionality with PPE Weight: 5	Power Weight: 3	Warranty Weight: 3
Multicomponent Measurement Weight: 4	Screen Visibility Weight: 4		
Reachback Weight: 4	Accessories Weight: 2		
Sample Classification Weight: 3	Administrative Controls Weight: 2		
Data Export Weight: 3	Sample Labelling Weight: 1		



3.0 ASSESSMENT METHODOLOGY

Products were assessed over five days at NUSTL. Instruments were evaluated through a combination of hands-on operational use and review of manufacturer-verified product specifications for features that could not be assessed operationally. To allow evaluators to experience different features of the spectrometers and observe how they perform identifications, aliquots of seven innocuous materials in various types of containers were prepared in advance by PNNL then used as blind test substances. NUSTL provided each team of evaluators with an identical set of the seven samples, which were labelled with an alpha-numeric code so they could be later matched to a key showing their contents. First, vendor product specialists trained the evaluators on each spectrometer, then evaluators practiced using each one with the vendor representative to analyze three of the samples. After that, the evaluators operated the device independently to analyze the other four samples.

Throughout the assessment, evaluators worked in three teams of two responders. In each of the operational tests, the team analyzed a sample after following manufacturer-recommended procedures for preparing the sampling probe, power setting, and analysis library. Instruments were set to analyze test samples for no longer than two minutes. The resulting spectra were either saved to an onboard memory or emailed to NUSTL.

NUSTL and PNNL data collectors shadowed the teams to observe evaluators and to document both evaluators' feedback and the sample identification results for each product. A PNNL scientist who is an experienced user of and subject matter expert (SME) on Raman spectrometers and who had previously conducted laboratory tests on the instruments observed the teams and served as a resource to help resolve questions about sample verifications where there was ambiguity in sample composition relative to product libraries.



3.1 Phase 1: Product Information Overview

Before operationally testing the device, evaluators were given vendor-provided product information and specifications which were confirmed by vendors prior to the assessment.

Each vendor product representative provided an overview of their respective instrument, covering features and capabilities and demonstrated how to start-up and calibrate the instrument as would be required for a responder arriving at a hazmat incident.

Evaluation criteria assessed during this phase included the following:

Evaluation Criteria Assessed
Library
Measurement Capabilities
Reachback
Data Export
Accessories
Administrative Controls
Durability
Decontamination
Power
Calibration Requirements
Consumables
Warranty



Figure 3-1 Raman Spectrometer Familiarization Sessions

3.2 Phase 2: Operational Assessment

Evaluators assessed each handheld Raman spectrometer based on scripted activities they performed with it. They also had access to each product’s reference material including quick-start guides (if available) and manuals.

Participants assessed the products by using various instrument features and capabilities and conducting analyses of test samples. Evaluators used the instruments one at a time and completed the assessment worksheets for each product before assessing the next.



Evaluation criteria assessed during this phase included the following:

Evaluation Criteria Assessed
Measurement Capabilities
Sample Identification Through Containers
Multicomponent Measurement
Data Export
Sample Classification
Ease of Use
Functionality with PPE
Spectrum Analysis Tools
Screen Visibility
Accessories
Sample Labeling
Decontamination
Power



Figure 3-2 Raman Spectrometer Operational Activities

3.2.1 Hands On Product Familiarization

Evaluators became familiar with the operations of each instrument and its associated accessories so they could use it with little or no assistance from the vendor’s representative. First, however, the representatives demonstrated how to perform sample analyses using one or more demonstration samples they had brought to the assessment for training.

Each evaluator team member then analyzed a blind test sample from among those shown in Table 3-1 while following the manufacturer-recommended procedure that specifies details on use of accessories (e.g. sampling probe), power setting, and analysis library to use. Instruments were set to analyze samples for no longer than two minutes. Evaluators worked with product representatives as closely as needed to properly understand how to perform sample analyses.

Once each analysis had been correctly performed according to the manufacturer-recommended procedure, the acquired spectrum file was saved to onboard memory or sent via email. If the instrument did not correctly identify the compounds present in a test sample, that sample was not reanalyzed as long as the manufacturer-recommended procedure was correctly followed.

NUSTL documented the analyses results obtained during this session on worksheets and made them available for reference in the later debriefing session during which the evaluators scored the instrument’s measurement capabilities.

Table 3-1 Test Samples 1-3

Sample ID	Container/Format	Contents	Comments
A-1, B-1, C-1	Plastic bag	Baking soda	<ul style="list-style-type: none"> Each evaluator analyzes a different test sample (e.g., A-1, A-2, or A3), analyzing it once Product rep works closely with evaluators to ensure they understand correct instrument operation
A-2, B-2, C-2	Gel cap	Caffeine	
A-3, B-3, C-3	Amber jar	Ammonium Nitrate	
<p>Samples IDs begin with A, B, or C before the sample number to denote those samples used by teams A, B, and C, respectively.</p>			

3.2.2 Analysis of Test Samples

In this session the evaluators analyzed three additional test samples with little to no assistance from the product specialist. The product representative observed as evaluators performed test sample analyses but only interacted with the evaluators as needed, e.g., to correct errors in an evaluator’s analysis technique or to answer evaluator questions.

The PNNL scientist who is an experienced user of Raman spectrometers adjudicated spectrometer any analysis results that were ambiguous. For example, the measurement result for sample number 6, powdered milk, may have correctly identified one of the many chemical components in powdered milk though, it did not label the result as milk powder.

Each of the evaluation team members analyzed one of the test samples from Table 3-2, analyzing the sample twice. The third sample was analyzed once. Each analysis was performed following a manufacturer-recommended procedure that specifies details such as use of sampling accessories, power settings, and which library to use for analysis. Instruments were set to analyze test samples for no longer than two minutes. If an instrument did not correctly identify the compound present in a test sample, that sample was not reanalyzed, so long as the manufacturer recommended procedure had been followed correctly.

NUSTL made analysis results obtained during this session available to the evaluators for reference during the debriefing session when the instruments were scored on measurement capabilities.

Table 3-2 Test Samples 4-6

Sample ID	Container/Format	Contents	Comments
A-4, B-4, C-4	Aspirin bottle	Aspirin tablets	<ul style="list-style-type: none"> Each evaluator analyzed a different test sample, analyzing it twice Milk powder is fluorescent; the ability to compensate for sample fluorescence is one factor for consideration in rating an instrument's measurement capabilities
A-5, B-5, C-5	Amber jar	Baking soda	
A-6, B-6, C-6	Plastic bag	Milk powder (fluorescent)	
Samples IDs labelled A, B, and C denote those used by the respective teams.			

Next, each evaluator analyzed the multicomponent test sample shown in Table 3-3, which was a mixture of two solid chemical compounds. The test sample was analyzed three times in total per team, twice by one evaluator and once by the other. As in the previous sessions, the product representatives and PNNL scientist observed while evaluators performed test sample analyses but interacted with the evaluators only when needed, for instance, to answer an evaluator's questions or to correct errors in an evaluator's analysis technique.

Table 3-3 Multicomponent Test Sample

Sample ID	Container/Format	Contents	Comments
A-7, B-7, C-7	Plastic Bag	Mannitol & Caffeine (40%/60%)	<ul style="list-style-type: none"> Team should acquire three analysis results
Samples IDs labelled A, B, and C denote those used the respective teams.			

Once an analysis was performed correctly according to the manufacturer recommended procedure, the acquired spectrum file was saved to onboard memory or sent via email.

After all analyses of the multicomponent test sample were completed, product representatives worked with the evaluator teams to re-analyze the multicomponent sample spectrum file using onboard (or laptop-connected) spectrum analysis tools. The representatives used any remaining session time to demonstrate additional analysis capabilities that may not have been addressed during the analyses of the test samples. For instance, some instruments are able to make standoff measurements or have additional sampling probes that are particularly useful for analyzing samples in certain container types or physical formats (e.g., pills).



3.3 Data Gathering and Analysis

After each set of assessment activities, data collectors used a questionnaire to record the evaluators' scores for each product according to the criteria listed in Section 2.0. The questionnaire included specific questions for each criterion, which the data collectors read to the evaluators. Evaluators 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 all assessment devices were scored for each of the activities, evaluators had an opportunity to review their criteria ratings and comments for all products and to adjust them if desired. For criteria that were rated by the evaluators multiple times throughout the assessment, NUSTL assigned final averaged ratings. NUSTL calculated the overall averaged assessment and category scores for each product using the formulas in Appendix B.

Data collectors also captured comments on advantages and disadvantages (see table 5-1) as well as general comments regarding the assessed products and the assessment process. These evaluator comments are summarized in this assessment report.

Additionally, PNNL laboratory tested all ten instruments were at prior to the assessment to obtain data about the instruments that helped to design the assessment. The testing work included determining each spectrometer's ability to identify

- samples in different types of containers that responders often encounter
- samples containing one or more chemical compounds
- fluorescent samples
- chemicals with different properties (e.g., solids, liquids)

PNNL also tested performance of the reachback support provided by instrument manufacturers that offer that service. Results of these lab tests are captured in a limited distribution report that can be provided upon request to federal, state, local, tribal, and territorial responders only by emailing NUSTL at NUSTL@hq.dhs.gov.

4.0 ASSESSMENT RESULTS

Overall scores for the assessed products ranged from 2.8 to 4.3. Assessment results are presented in Table 4-1. Additional comments on each product are provided in Sections 4.1–4.10. Evaluators concluded that three of handheld Raman spectrometers met all of their expectations.

Table 4-1 presents the overall assessment score and category scores for each product. Products are listed in order from highest to lowest overall assessment score throughout this section. To calculate the overall score, NUSTL uses the raw scores for each category, prior to rounding. Products with the same rounded overall score are listed in order based on the raw data. The criteria that constitute each category and their definitions are provided in Appendix A.

Table 4-1 Overall Assessment Results

Product	Overall Score					Overall	Capability	Usability	Deployability	Maintainability
	0	1	2	3	4					
Agilent-Resolve						4.3	4.5	4.4	4.2	3.7
Thermo Scientific-Gemini						4.2	4.3	4.4	3.9	3.7
Thermo Scientific-First Defender RMX						4.0	4.0	4.2	4.1	3.8
Rigaku-ResQ CQL						3.9	4.1	4.1	3.6	3.7
B&W-TacticID-1064 ST						3.8	3.8	4.2	3.8	3.4
Metrohm-Mira DS						3.5	3.5	3.7	3.5	3.3
Smiths Detection-ACE-ID						3.0	2.6	3.3	3.2	3.6
Serstech-Arx						3.0	2.5	3.1	3.2	3.9
Pendar-X10						2.9	3.1	2.9	2.4	3.1
Chemring-PGR-1064						2.8	2.4	2.7	3.3	3.5

Scoring key: 1 (least favorable) to 5 (most favorable)



Table 4-2 presents the average evaluation criteria scores the products received from the evaluators for each evaluation criterion. A green, fully shaded circle represents the highest rating, while a red, unshaded circle represents the lowest rating. A version of this table was previously published with errors on the SAVER website. The corrected version is republished here with accurate graphical ratings.

Table 4-2 Evaluation Criteria Ratings

Key		Products									
SAVER Category	Evaluation Criteria	Agilent Resolve	Thermo Scientific Gemini	Thermo Scientific First Defender RMX	Rigaku ResQ CQL	B&W TacticID	Metrohm Mira DS	Smiths Detection Ace ID	Serstech Arx	Pendar X10	Chemring PGR 1064
Capability	Library†										
	Measurement Capabilities‡										
	Sample Identification Through Containers*										
	Multicomponent Measurement*										
	Reachback†										
	Data Export‡										
	Sample Classification*										
Usability	Ease of Use*										
	Functionality with PPE*										
	Spectrum Analysis Tools*										
	Screen Visibility*										
	Accessories‡										
	Administrative Controls†										
	Sample Labeling*										
Deployability	Durability†										
	Decontamination‡										
	Power‡										
Maintainability	Calibration Requirements†										
	Consumables†										
	Warranty†										

Notes: * Assessed operationally
 † Assessed by specification

‡ Assessed both operationally and by specification

4.1 Agilent Resolve

The Agilent Resolve received an overall assessment score of 4.3 and costs \$65–72,000. The Resolve measures 6.1 x 11.4 x 2.9 inches and weighs 4.9 pounds (including the battery). It has a rechargeable lithium-ion battery with a four-hour run time. The unit has a class 3B 830 nm laser with adjustable laser power up to 475 milliwatt (mW). Its large display and buttons are designed for use while wearing personal protective equipment (PPE). It has an IP rating of 67 and is also shock-, drop- and vibration-tested to MIL-STD-810G. The Resolve can operate in temperatures between -4 and 122 °F.

The Resolve can be purchased with a variety of spectral library types and sizes. The hazmat library package contains 5,500 spectra including drugs, explosives, chemical warfare agents (CWAs), toxic industrial chemicals and toxic industrial materials (TICs/TIMs), and household chemicals. The comprehensive package contains roughly 13,000 spectra. With any of the available library configurations, users can customize or create libraries to fit their specific needs.

Accessories provided with purchase include a calibration piece, laser safety glasses, a shoulder strap, carry case, two vendor-specific lithium-ion battery packs, one single-bay charger, and a vial holder adapter. A one-year warranty is included at the time of purchase with the option to purchase an extended warranty. Reachback service is available and included as part of the warranty package.

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

4.1.1 Capability

The Resolve received a Capability score of 4.5 The following information is based on evaluator comments:

- **Library:** One evaluator found the Resolve exceeded their expectations based on the tiers and numbering approach in the libraries, as well as the ability to create individual libraries, the ability to display meta data icons for them and other features. The majority of evaluators found the library met all of their expectations; these evaluators highlighted advantageous features such as the ability to push library updates to all spectrometers in a group . One evaluator indicated it met most of their expectations, attributing this rating to the library's missing TICS/TIMS and chemical warfare agents and the inability for users to add notes or tags to samples.



Figure 4-1 Agilent Resolve

- **Measurement Capabilities:** The majority of evaluators found the Resolve’s measurement capabilities exceeded their expectations. They attributed this to the easy-to-adjust power settings available, its recommended modes of operation and intervals of delayed sampling. Other features the evaluators valued included the spectrometer’s warnings when scanning fluorescent samples and when ambient light is too bright for sampling. The Resolve’s capability to penetrate opaque and dark containers (established by scanning through an amber container (Figure 4-2)) also factored into the scoring.



Figure 4-2 Evaluator scanning through an amber container

- **Sample Identification Through Containers:** For this criterion, the Resolve exceeded all evaluators’ expectations. Evaluators valued features such as its three scanning modes (barrier, direct and vial), capability to identify the container type prior to beginning scan, having a visual focal point and accurately detecting various samples throughout the assessment.
- **Reachback:** Evaluators gave mixed feedback on the reachback support offered for the Resolve. One indicated it exceeded their expectations as it offers the ability to request support from the instrument itself via Wi-Fi, laptop or website. Two evaluators said it met all their expectations. Three said it met most expectations and attributed this score to reachback being available at no cost only while the instrument is under warranty and to the length of time it takes to receive a response (estimated as up to 24 hours).
- **Data Export:** The Resolve exceeded all evaluator expectations for data export as it can be done remotely via a mobile app, over the phone, from a Wi-Fi enabled computer or via USB. Evaluators also found the generated reports informative, customizable (i.e., with or without spectra overlay) and easy to interpret due to the effective use of color contrasts for overlaid spectra.

4.1.2 Usability

The Agilent Resolve received a Usability score of 4.4. The following information is based on evaluator comments:

- **Ease of Use:** All evaluators found the Resolve either exceeded or met all their expectations for ease of use. Evaluators found the spectrometer intuitive and its menus easy to navigate. They also valued that device can be used remotely, and appreciated the vendor-provided guide sheets, which were easy to understand. However, evaluators also noted Resolve’s lack of touch screen and bulky form factor were not optimal for operations.

- **Screen Visibility:** Evaluators offered mixed feedback on the screen visibility of the Resolve (Figure 4-3). Four evaluators found it exceeded their expectations, while three said it met most of them. Those who chose “exceeded” attributed this score to the screen being clear and having good color contrast, the text being in a large font, and other features including as auto rotating, resizing and dimming. (Some?) evaluators noted the spectrometer is difficult to read when not looking straight at the device.
- **Sample Labeling:** Evaluators had mixed feedback on sample labeling. The Agilent Resolve does not allow users to add comments or supplementary information, only meta data after analysis. This resulted in three evaluators saying it met some or none of their expectations. The other three evaluators said it met all or some of their expectations.



Figure 4-3 Agilent Resolve screen display during sample identification

4.1.3 Deployability

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

- **Decontamination:** All evaluators found the Resolve either exceeded or met all their expectations for decontamination. They cited the device’s IP67 rating as well as their own observation that the unit had no crevices, was outfitted with a removable bumper, and had port covers (Figure 4-4).
- **Power:** Resolve operates off a rechargeable lithium-ion battery that has an estimated run time of four hours. The battery is not hot swappable. Two evaluators said this met all of their expectations, and four found it met most. Three of the evaluators who said it met most of their expectations expressed concern about the lack of a hot swappable battery. One specifically noted a battery change requires users to shut down and restart the device, which has a lengthy power up cycle.



Figure 4-4 Resolve port covers

4.1.4 Maintainability

The Resolve received a Maintainability score of 3.7. The following information is based on evaluator comments:

- **Warranty:** The Resolve includes a one-year warranty at the time of purchase. Additional warranties are available for purchase, including one that allows for loaner options. All evaluators indicated that this met most of their expectations, attributing this rating to the limited duration and estimated turnaround time of repairs, which could be up to four weeks.

4.2 Thermo Scientific Gemini

The Thermo Scientific Gemini received an overall assessment score of 4.2 and costs \$105– 134,000. The Gemini is an integrated handheld Raman and FTIR instrument. The unit measures 10.1 x 5.7 x 2.4 inches and weighs 4.2 pounds. The Gemini can be powered using a wall adapter or hot-swappable lithium-ion batteries (rechargeable or disposable 123A). A runtime of more than six-hours is typical for the unit. The Raman analysis uses a class 3B 785 nm laser with adjustable laser power up to 250 mW. A fiber optic probe and separate vial compartment are built in for Raman analysis. The unit has an IP rating of 67 and meets MIL-STD-810G requirements. The Gemini can be operated in temperatures between -4 and 122 °F.

A spectral library of more than 16,000 compounds including explosives, toxic industrial chemicals, CWAs, narcotics, precursors, and white powders is provided. Users can create custom libraries based on their needs. The instrument has a menu driven interface.

A standard one-year warranty is included, with additional years available for purchase. Both 24/7 technical and reachback support are provided.

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

4.2.1 Capability

The Gemini received a Capability score of 4.3. The following information is based on evaluator comments:

- **Measurement Capabilities:** All evaluators found the Gemini's measurement capabilities exceeded or met all of their expectations. They attributed their ratings to the visibility of the laser's focal point, the wand's flexibility for collecting samples (Figure 4-6) and the device's capacity to read fluorescent samples.
- **Sample Identification Through Containers:** All evaluators found the Gemini's ability to identify a sample through containers exceeded or met all of their expectations. Evaluators cited the ease of sampling through all of the various container types used and the ease of obtaining the confidence value for a sample.
- **Reachback:** Evaluators gave mixed feedback related to reachback. Two of the evaluators found Gemini's reachback exceeded their expectations. Two others found it met all of their expectations, noting that results were provided within an hour and that contact information is located on the back of the instrument. Two other evaluators said it met most of their expectations; while they appreciated that reachback was available 24 hours a day, seven days a week, it is only available for instruments under warranty and could be prohibitively costly outside of warranty coverage.



Figure 4-5 Thermo Scientific Gemini



Figure 4-6 Responder using the Gemini for sampling

- **Sample Classification:** All evaluators found the Gemini exceeded or met all of their expectations. Evaluators stated it provides a great deal of information including NIOSH references, sample synonyms, physical descriptions and warning of fluorescent samples. Evaluators noted, however, that incorporating warnings of explosives detected and using warning symbols (in lieu of text) would be beneficial for end users.
- **Data Export:** Four evaluators found the Gemini met all their expectations; two found it met most. Evaluators considered the option to export all spectra from a session, instead of individually, beneficial for operations. They also noted that they would have liked additional methods for extracting data (e.g., USB, Bluetooth, Wi-Fi).

4.2.2 Usability

The Gemini received a Usability score of 4.4. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Evaluators found the Gemini exceeded, met all or met most of their expectations. One evaluator highlighted the capability to overlay spectra on the display screen as a plus. On the contrary, another evaluator found the overlay display made it harder to judge the degree of match.
- **Ease of Use:** The Gemini exceeded ease-of-use expectations of all the evaluators. Evaluators attributed this rating The intuitive interface, large buttons, sampling wand and impressive pre-questions. They also found the vendor-provided field operations guides easy to follow.
- **Functionality with PPE:** Evaluators were able to perform most critical functions with gloves on (Figure 4-7) and used the touch screen with both wet and dry nitrile or butyl gloves. This exceeded the expectations of all evaluators.
- **Screen Visibility:** All evaluators found the Gemini’s screen visibility exceeded or met all of their expectations. The Gemini features auto dimming and backlit buttons. Evaluators found the instrument worked well in darkness and had limited glare in bright light situations.



Figure 4-7 Evaluator operating the Gemini while wearing gloves

4.2.3 Deployability

The Gemini received a Deployability score of 3.9. The following information is based on evaluator comments:

- **Durability:** The durability of the Gemini met all expectations of four evaluators and most expectations of two. One evaluator noted the power port and SD card port covers (circled in Figure 4-8) were hard to get on and could be torn off and/or lost. They also found it difficult to know if the unit was completely sealed.



Figure 4-8 Gemini power ports and SD card locations

- **Decontamination:** The ability to decontaminate the Gemini met all expectations of four evaluators as it is submersible when fully sealed and a 10% bleach solution can be used. Two evaluators found this met most of their expectations, one of whom attributed this rating to the wand's needing to be decontaminated because it comes in direct contact with the sample. They also expressed concern about decontaminating the rubber boot due to its proximity to ports.
- **Power:** The Gemini exceeded or met expectations of all evaluators for this criterion as the battery is hot swappable and users have the option of supplementing the rechargeable battery with additional CR123s to extend battery life.

4.2.4 Maintainability

The Gemini received a Maintainability score of 3.7. The following information is based on evaluator comments:

- **Calibration Requirements:** Two evaluators found calibration requirements exceeded their expectations since no calibration is needed. Four evaluators found the Gemini met most of their expectations as the product uses only a "check sample" and doesn't offer true calibration.

4.3 Thermo Scientific First Defender RMX

The Thermo Scientific First Defender RMX received an overall assessment score of 4.0 and costs \$64-\$80,000. The First Defender RMX measures 7.7 x 4.5 x 2.4 inches and weighs 2.0 pounds. The system can be powered using a wall adapter or lithium-ion batteries (rechargeable or disposable 123A). A runtime of more than four-hours is typical. It has a class 3B 785 nm laser with an adjustable laser power that can be adjusted to 75, 125, or 250 mW. The instrument meets MIL-STD-810G shock and vibration specifications and has an IP rating of 67. The FirstDefender RMX can be operated in temperatures between -4 and 122 °F.

A spectral library of more than 12,000 compounds including explosives, toxic industrial chemicals, CWAs, narcotics, precursors, and white powders is provided. Users can create custom libraries based on their needs. The instrument has a menu-driven interface.

The FirstDefender can be used for point-and-shoot sampling or for measuring samples in a vial with the integrated vial holder. The RMX has a fiber optic probe for sampling. The probe is used for placement of the laser relative to the sample. Also, a sample and the laser probe can be covered to block interfering ambient light without blocking the instrument controls and display. The FirstDefender RMX unit can be used as a handheld unit with a fixed probe or through an integrated vial mode. It can also be mounted onto a tactical robot using an integration kit from the robot manufacturer for mounting and universal control.

Both 24/7 technical and reachback support are provided.



Figure 4-9 Thermo Scientific First Defender RMX

4.3.1 Capability

The First Defender RMX received a Capability score of 4.0. The following information is based on evaluator comments:

- **Library:** All evaluators found the library met all of their expectations. The library includes 12,000 compounds and allows the user to create a reference library and tag features, rename files, add spectra to the library, and tag up to 50 spectra as they are collected with meta data (e.g., “amber jar in suspect’s basement”).
- **Measurement Capabilities:** All evaluators found the First Defender RMX met all of their expectations for measurement capabilities. They noted the availability and flexibility of the sampling wand (Figure 4-10) is valuable for ease of use when samples are at odd angles or for long measurement times. They also appreciated the scan delay, the capability to tag spectra for future use and their being able to see the laser focal point.
- **Sample Identification Through Containers:** All evaluators found the First Defender RMX exceeded or met all of their expectations. They noted its capability to detect all samples through various container types (e.g., plastic bags, bottles, darkened containers). One evaluator appreciated the visibility of the laser focal point, while another noted that the focal point is non-adjustable and the device only offers the option to measure with or without the nose cone.
- **Reachback:** Evaluators supplied mixed feedback related to reachback. Two of the evaluators found it exceeded their expectations. Two others found it met all of their expectations, noting that results were provided within an hour and that contact information is located on the back of the instrument. Two other evaluators found it met most of their expectations, noting that while they appreciated that reachback was available 24 hours a day, seven days a week, reachback is only available for instruments under warranty and could be prohibitively costly outside of warranty coverage.
- **Data Export:** Evaluators had mixed feedback related to the First Defender RMX’ data export options. It met all expectations of one evaluator and most or some of the expectations of the other five evaluators. Evaluators noted the micro SD card and the inability to extract files in PDF format as limitations. One evaluator also found the card difficult to remove but noted that the SD to USB adaptor was easy to use. Evaluators would have liked additional methods for extracting data (e.g., USB, Bluetooth).



Figure 4-10 Evaluator using the First Defender RMX wand to scan a sample

4.3.2 Usability

The First Defender RMX received a Usability score of 4.2. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Four evaluators found the First Defender RMX met all of their expectations for spectrum analysis. Two found it met most, one of whom indicated they would have preferred confidence levels to be visible and noted that it took a lot of navigating in order to cross-reference spectra.

- **Ease of Use:** The ease of use of the First Defender RMX exceeded or met all of the evaluators' expectations. They found the instrument interface intuitive and simple to use given its four primary menu options. Evaluators appreciated that instructions for use were located on the back of the instrument and that the cursor was highlighted on the display screen. One evaluator noted that a touch screen would be a valuable addition.
- **Screen Visibility:** All evaluators found the screen visibility exceeded or met all of their expectations. The First Defender RMX offers the ability to expand the screen, which enhances visibility. Evaluators found the instrument worked well in both darkness and bright light.
- **Administrative Controls:** The majority of evaluators found administrative controls met all their expectations. They based their rating on this unit's having minimal control levels (two), the inability for non-administrator users to delete files, and admin level users' capability to tag spectra to assist inexperienced users. One evaluator found it met most of their expectation and, contrary to the others, attributed this higher rating it to the device's offering only two levels of control.
- **Sample Labeling:** Two evaluators found the sample labeling met all their expectations as files can be renamed (e.g., to include case file number). Four evaluators stated it met most of their expectations but they would have liked the color scheme to change to provide confidence information more accurately and would have appreciated having the ability to tag samples with metadata.



Figure 4-11 First Defender RMX being operated with gloved hands

4.3.3 Deployability

The First Defender RMX received a Deployability score of 4.1. The following information is based on evaluator comments:

- **Durability:** Evaluators gave mixed feedback related to the durability of the First Defender RMX. Four evaluators found the instrument exceeded or met all of their expectations, with one of them highlighting the ruggedness of the device, including its port closures (Figure 4-12), and removable sleeve for cleaning. Two evaluators said it met most of their expectations; one remarked that the battery compartment door and closure would require the user take care when closing.
- **Decontamination:** The ability to decontaminate the instrument exceeded expectations of one evaluator and met all expectations of five evaluators, all of whom noted it is submersible when fully sealed and a 10% bleach solution can be used. One evaluator noted using the wand might limit the contamination to a single location, the tip of the wand, instead of the entire instrument.



Figure 4-12 First Defender RMX port closures

- **Power:** Evaluators had mixed feedback related to power. Two evaluators found it exceeded their expectation and two said it met all, citing the two available back-up batteries that allow the unit up to twelve hours of run time. Two evaluators said the First Defender RMX's power options met most of their expectations, noting the batteries are not hot swappable.

4.3.4 Maintainability

The First Defender RMX received a Maintainability score of 3.8. The following information is based on evaluator comments:

- **Calibration Requirements:** Two evaluators found the First Defender RMX exceeded their expectations, attributing this to the instrument's not needing to be recalibrated and its capability to send a diagnostic file to Thermo Fisher reachback to gauge functionality.

4.4 Rigaku ResQ CQL

The Rigaku ResQ CQL received an overall assessment score of 3.9 and costs \$46,000. The ResQ CQL is 7.28 x 5.9 x 3.11 inches and weighs 3.25 pounds. The ResQ CQL features a hot swappable rechargeable lithium polymer battery with a 5- to 7-hour runtime. The unit is also compatible with CR123A disposable batteries. The unit has a class 3B 1064 nm laser with operator- adjustable laser power up to 490 mW. The unit has been third-party tested and certified to meet an IP68 rating and MIL-STD-810G requirements. The ResQ CQL can be operated continuously at temperatures between -4 and 104 °F (intermittently, up to 122 °F).



Figure 4-13 Rigaku ResQ CQL

The ResQ CQL can be operated by a touchscreen display or large button navigation for use when wearing PPE. A library of up to 13,000 compounds including CWA, explosives, precursors, TICs/TIMs, narcotics, precursors, and cutting agents is included in the list price. Data can be transferred via WiFi or USB connection. An integrated five-megapixel digital camera allows operators to add picture evidence into the analytical reports. The instrument contains four user levels with varying permissions.

A base adapter and tablet/universal adapter are included as accessories for scanning a variety of material and containers. A specialized vial holder, periscope adapter, and bottle adapter are available for purchase from Rigaku to further accommodate sampling needs. Additionally, the separate company DetectaChem makes QuickDetect software and colorimetric test strips that can be used with the ResQ CQL for detecting trace amounts of explosives and narcotics. A two-year warranty is included with extended warranty options available. Free software upgrades, library updates, and access to 24/7/365 reachback support for the life of the unit are all included with the purchase of the ResQ CQL.

4.4.1 Capability

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

- **Library:** Evaluators had mixed feedback for the library criterion. Three evaluators found it exceeded their expectations and one found it met all of theirs as the library includes 11,000 compounds and it is updated at no additional cost for the life of the product. Two evaluators stated the device library met most of their expectations.

- **Measurement Capabilities:** All evaluators found the ResQ CQL’s measurement capabilities exceeded or meet all of their expectations. They attributed their scores partly to the device’s ability to detect samples through fluorescent interference.
- **Sample Identification Through Containers:** All evaluators found the ResQ CQL’s capacity to identify samples through containers exceeded or met all of their expectations. Three evaluators found it advantageous to see the laser and focal point while sampling; another added that being able to see the signal-to-noise ratio helped them to determine whether the device captured an acceptable scan or whether the focal point needed adjusting.



Figure 4-14 Rigaku ResQ CQL collecting a sample through an amber container

- **Multicomponent Measurements:** All evaluators found the ResQ CQL exceeded or met all of their expectations. Evaluators commented that the device identified multiple and individual components, not just the primary component.
- **Reachback:** Evaluators supplied mixed feedback on reachback. Two evaluators found that the device met all their expectations, two found it met most, and two, that it met some. Those who found it met most or some of their expectations noted that reachback staffing is limited to one person, which could impact response time. Evaluators did appreciate that the phone number for reachback is located conveniently on the back of the device and that reachback is offered for the lifetime of the instrument.



Figure 4-15 Rigaku ResQ CQL

- **Sample Classification:** The majority of evaluators found the ResQ CQL exceeded their expectations for sample classification. One evaluator found it met all their expectations. Evaluators commented that the device provides useful additional information for interpreting results, such as “cutting agent” for compounds that are commonly used as cutting agents for other dangerous substances. One evaluator remarked that adding a “danger level” indicator for identified compounds could benefit users’ situational awareness.
- **Data Export:** Three evaluators found the device’s ability to export data via USB (Figure 4-16) or Wi-Fi met all their expectations, two found it met most, and one found it met some. One evaluator said the process for data export, but another evaluator noted that Wi-Fi exporting might not be usable in the field. One evaluator had concerns about what they perceived as a lack of data security.



Figure 4-16 Data export via USB

4.4.2 Usability

The ResQ CQL received a Usability score of 4.1. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** All evaluators found the instrument exceeded or met all expectations. Three evaluators remarked on the usefulness of the capability to overlay spectra; one added that the overlay tools were user-friendly and easy to find due to the screen size. One evaluator reported difficulty using the buttons and would have preferred if the instrument allowed for finger sweeping. Another evaluator noted appreciated that no proprietary software is needed.
- **Ease of Use:** Four evaluators found the device exceeded their expectations for ease of use as the instrument was intuitive, outfitted with large buttons, and required using only two buttons for most operations. Two evaluators said the device met most of their expectations, one of whom found the interface complex and lost their place while navigating.
- **Functionality with PPE:** Evaluators had mixed feedback on the ResQ CQL's functionality with PPE (Figure 4-17). Two evaluators found it exceeded their expectations as the touchscreen work for them with both wet and dry butyl gloves. Four evaluators who found it met most or some of their expectations based their ratings on difficulties they experienced when wearing with gloves. They were concerned that pressing the wrong buttons could be an issue. One evaluator suggested that Rigaku could mitigate these concerns by including a stylus for use with the touch screen.
- **Screen Visibility:** Four evaluators found the screen visibility exceeded their expectations, which they attributed to the large size of the screen and icons. This also contributed to the screen being easy to read from an angle. Two evaluators found it met most of their expectations, saying they would have preferred the buttons be backlit to enhance usability in low-light conditions.
- **Accessories:** The device met all or most expectations for evaluators. However, one evaluator suggested commonly used items such as vials or a periscope for measuring bulk chemicals on flat surfaces should come standard with the instrument.
- **Sample Labeling:** The ResQ CQL exceeded or met all expectations for sample labeling for five of the evaluators, who appreciated its capability for adding notes and images to sample scans. One evaluator commented that the ability to change file names, however, could be a hinderance for law enforcement applications.




Figure 4-17 Rigaku ResQ CQL being operated with gloves

4.4.3 Deployability

The ResQ CQL received a Deployability score of 3.6. The following information is based on evaluator comments:

- **Durability:** Evaluator feedback ranged from the unit exceeding expectations to meeting some expectations. The ResQ CQL has an IP68 rating, which exceeded expectations for two evaluators. One evaluator said it met all of their expectations. The three evaluators that found



it met most or some of their expectations expressed concern that the large screen could be vulnerable to cracks or scratches; they also suggested decontamination methods could damage the device over time, noting that the screw atop the instrument may not be sufficient ingress protection over time.

- **Decontamination:** Evaluators gave mixed feedback on decontamination. Two evaluators found it met all their expectations, while another two stated it met most, and two more said it met some of their expectations. Evaluators expressed concern about the lack of a USB port cover, the cover on the camera, the screw atop the instrument, crevices on the instrument, and its porous strap.
- **Power:** Most evaluators found the device exceeded their expectations for this criterion, while two evaluators said it met either all or most of their expectations. Evaluators found it advantageous that the ResQ CQL runs on non-proprietary rechargeable batteries that are hot-swappable. Evaluators also found battery replacement intuitive and appreciated that the battery door remains connected to the instrument during the replacement process.

4.4.4 Maintainability

The ResQ CQL received a Maintainability score of 3.7. The following information is based on evaluator comments:

- **Calibration Requirements:** Evaluators offered mixed feedback on calibration requirements. Two evaluators found the ResQ CQL exceeded their expectations, one found it met most, and three, some expectations. The instrument takes roughly two minutes to calibrate and uses benzophenone as its calibration standard. One evaluator commented this method is effective for improving the instrument's responses in-house without having to send it back to the manufacturer for testing or repairs.
- **Consumables:** Two evaluators found the consumables met all their expectations, one of whom noted the benefit of the instrument using non-proprietary vials. Four evaluators found the consumables met most of their expectations. The sample vial holder accessory for the instrument can be adjusted to fit different sized vials that can be purchased from any supply company. One evaluator commented that the twenty vials that come with the device is not very many and would be spent in a very short time span.
- **Warranty:** The ResQ CQL offers a two-year warranty as well as loaner program during repair and lifetime reachback. This exceeded, met all or met most expectations of the evaluators.

4.5 B&W Tek TacticID-1064

The B&W TEK TacticID-1064 received an overall assessment score of 3.8 and costs \$44,500. The TacticID-1064 measures 9.8 x 4.3 x 2.4 inches and weighs 3.4 pounds. It uses a rechargeable lithium-ion battery with a four-hour runtime or can be powered with disposable CR123 batteries and an adapter. The unit has a class 3B 1064 nm laser with a laser power of 420 mW (adjustable in 1% increments). The TacticID-1064 is IP68 rated and MIL-810-G drop test compliant. It can be operated at temperatures between 14 and 122 °F.

Large buttons on the TacticID-1064 allow for use while wearing protective gear; hard button navigation can be used in place of touch screen. A library of over 10,000 spectra including explosives, chemicals, and narcotics is provided. Optional libraries include reference spectra of explosives and CWAs. Users can also create libraries to fit their specific needs or import existing libraries via USB.

With Bluetooth, Wi-Fi, and USB connectivity, detailed reports (including photos from the onboard camera) can be downloaded and synced to TID EX PC-based database and reporting software from any system. Reports can also be directly written to a USB drive.

A point-and-shoot adapter, vial holder, right-angled sampling adapter, and bottle adapters are included with purchase. A polystyrene validation cap is also provided for calibration purposes. Optional accessories include a contact immersion probe and large bottle adapter.

A two-year warranty is included at the time of purchase with the option to purchase the “Total Care” program which includes a loaner program for up to three years.

4.5.1 Capability

The TacticID-1064 received a Capability score of 3.8. The following information is based on evaluator comments:

- **Library:** The library for the TacticID-1064 exceeded or met all expectations for all evaluators. Evaluators found the library size, option to add more libraries at an affordable cost, and the capability for users to attach notes and photos to spectra were advantageous. However, one evaluator anticipated that entering notes on the instrument could be difficult or time consuming in the field due to its small onboard keyboard.
- **Sample Identification Through Containers:** Evaluators shared mixed feedback on this criterion. Two evaluators found the instrument exceeded their expectations, noting that scanning through an opaque label was successful using a two scan difference approach. Two evaluators found it met all expectations and remarked on the visibility of the laser focal point and the instrument’s successfully scanning through 4mm-thick containers. Finally, two evaluators found it met some of their expectations, having experienced difficulty using the TacticID-1064 to identify samples in plastic bags and having needed to experiment with tips for some samples.
- **Measurement Capabilities:** Most evaluators said the device met all their expectations; one evaluator said it exceeded their expectations. Evaluators found the adjustable laser power useful and that performing scans was easier with the visible laser. Two evaluators remarked that the device handled fluorescent interference well.



Figure 4-18 B&W TEK TacticID-1064

- **Multicomponent Measurements:** Four evaluators found the device met some of their expectations for multicomponent sampling and two evaluators found it met most of their expectations. Three evaluators noted that the device identified only one component when measuring the mixture samples.
- **Reachback:** Most evaluators found the device met some of their expectations for reachback, while one evaluator found it met all, and another found it exceeded their expectations. Reachback costs \$500 a year. Most evaluators expected it to be available at no cost with the purchase of the device. Evaluators were satisfied with its availability by phone or email 24 hours a day, seven days a week, as well as the expected response time of within two hours.
- **Sample Classification:** The TacticID-1064 exceeded or met expectations of all of the evaluators. Evaluators were satisfied by the instrument's use of both the Chemical Abstracts Service (CAS) registry numbers and the Globally Harmonized System (GHS) and appreciated the color-coding system (Figure 4-19) used by the device for different warnings and hazards. One evaluator also remarked that the instrument had no issues with fluorescence during the assessment .
- **Data Export:** All evaluators found the device exceeded or meet all their expectations. Many evaluators commented on its multiple and intuitive to use options for data export including USB, Wi-Fi and Bluetooth. Evaluators appreciated the thorough and concise reports the instrument outputs and that no proprietary software is needed to review results.

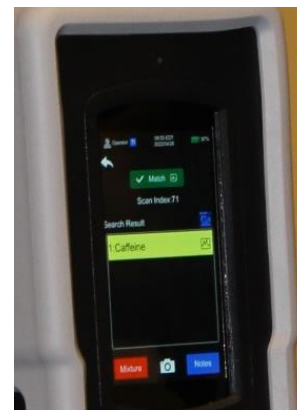


Figure 4-19 B&W TEK TacticID-1064 displaying identification

4.5.2 Usability

The TacticID-1064 received a Usability score of 4.2. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** All evaluators found the device exceeded or meet all expectations. Evaluators commented that it was useful to be able to overlay spectra, and that the overlays were easy to interpret on the device's screen (i.e., even without a laptop) (Figure 4-20). The color contrast when overlaying the spectra and the ability to zoom in on the screen using their fingers were considered beneficial for operational use.
- **Ease of Use:** Three evaluators found the device met all their expectations, while two found it exceeded and another that it met most of their expectations. The device contains a quick start guide which three evaluators commented on as effective and useful. One evaluator noted its quick sampling time and another remarked that its sampling accessories were simple and easy to swap.



Figure 4-20 B&W TEK TacticID-1064 spectra

However, two evaluators found it difficult to press buttons—one while wearing gloves and the other while working in a darker setting— due to their small size.

- **Functionality with PPE:** The TacticID-1064 exceeded or met all expectations for all evaluators except one who said it met most of their expectations. Evaluators found that the touchscreen worked when they had gloves on, but one evaluator found it difficult to operate. One evaluator also noted that the device comes with a stylus that can be used to operate the touchscreen or the device can be operated by using buttons while gloves are donned. Evaluators remarked the large font size and contrast in colors could be beneficial if the user is wearing a double face shield.
- **Screen Visibility:** Evaluators had mixed feedback for screen visibility. Two evaluators found that the device exceeded, two that it met all of and two that it met most of their expectations. One evaluator found the screen easy to read in all light settings, however others experienced difficulty reading the screen in bright light. Evaluators suggested the instrument's usability would be enhanced by the addition of backlit buttons, a backlit screen, a larger screen or adjustable backgrounds.
- **Accessories:** All evaluators found the accessories exceeded or met all of their expectations. Evaluators were satisfied by the multiple accessories for different sampling configurations. One commented on the camera quality, finding its resolution high enough for the application. Another noted the case for the accessories would be helpful in allowing responders to arrive incident ready. However, one evaluator noted that six accessories could be excessive for the field, and the straight tip adaptor cable did not lock on, presenting a risk of its getting lost.
- **Administrative Controls:** Four evaluators found the administrative controls met all their expectations, while two found it met most of their expectations. Two evaluators remarked that the feature of being able to create password-protected user and admin accounts was useful.
- **Sample Labeling:** The device exceeded or met all expectations for all evaluators except one who said it met most of their expectations. Evaluators appreciated the ability to add photos and notes to spectra, though one evaluator noted the sample spectra cannot be renamed. Another added that samples are labeled by number but they would prefer date and time labels.

4.5.3 Deployability

The TacticID-1064 received a Deployability score of 3.8. The following information is based on evaluator comments:

- **Durability:** The durability of the TacticID-1064 exceeded or met all evaluators' expectations. This was attributed to the instrument's IP68 rating, robust construction and protective case (Figure 4-21). Nonetheless, evaluators raised concerns about the strength and seal of the battery door as well as whether the brass tip accessory might be susceptible to damage.
- **Decontamination:** Two evaluators found the ability to decontaminate the TacticID-1064 exceeded their expectations, as the unit's shock protection can be removed and independently cleaned.



Figure 4-21 B&W TEK TacticID-1064 protective case

Four evaluators said it met most of their expectations and voiced concerns about the crevices in the shock protection and whether it would survive multiple or continuous cleaning over time.

- **Power:** Evaluators offered mixed feedback on this criterion. Two evaluators found it met all t, three found it met most, and one evaluator found it met only some of their expectations. Evaluators commented that the four-hour battery life is too short for their applications. They also remarked that they would prefer the device did not need to be plugged in to hot-swap the batteries. One evaluator found the batteries easily accessible while wearing gloves, while another struggled with the battery door cover finding it difficult to determine when it was sufficiently closed.

4.5.4 Maintainability

The TacticID-1064 received a Maintainability score of 3.4. The following information is based on evaluator comments:

- **Calibration Requirements:** The device's calibration requirements exceeded or met evaluators' expectations. The device does not require validation at start-up. One evaluator raised concern that the device should require validation, but another thought that the manufacturers are expecting users to recognize the need for validation. One evaluator added that the manufacturer will walk users through long term calibrations of the device as needed as part of the company's reachback. Another evaluator found it useful that the manufacturer provides a special procedure to recalibrate wavelength using a polystyrene calibration standard.
- **Warranty:** Five evaluators found that the warranty for the device met some expectations, and one evaluator found it met most expectations. Evaluator feedback included that the two-year warranty is sufficient, but the additional cost of \$4,000 cost to add a third year was too high. They noted that a loaner program is not included under the standard warranty. One evaluator highlighted that the lifetime warranty on hardware and troubleshooting is beneficial.

4.6 Metrohm Mira DS

The Metrohm Mira DS received an overall assessment score of 3.5 and the price starts at \$30,700. The Mira DS measures 3.5 x 5.0 x 1.8 inches and weighs 1.6 pounds. The Mira DS systems use two AA lithium-ion batteries with a four-hour runtime. Single use lithium-ion batteries are recommended. An optional rechargeable lithium-ion power supply provides a 16-hour runtime. The unit has a class 3B 785 nm laser with a laser power of 20-100mW (five adjustable laser power settings). The unit has an IP rating of 67 and meets MIL-STD-810G specifications for temperature, vibration, and shock. The Mira DS can be operated at temperatures between -4 and 122° F.

The Mira DS's laser uses raster scanning to measure a larger surface area of a sample, potentially better accounting for heterogeneous sample. A library of 1,200 compounds is provided, with more specialized libraries based on application available for purchase. Data can be transferred via Bluetooth or USB connection. MiraCal Mobile allows remote operation of the instrument as well as the addition of photographs and other metadata when generating or exporting a scan or report.



Figure 4-22 Metrohm Mira DS



The Mira DS comes in three package options: the Mira DS Basic, the Mira DS Advanced, and the Mira DS Flex. All packages include MiraCal DS operating and management software, the illicit materials library, and access to the MiraCal mobile app for Android. The Basic package also includes the calibration standard, a USB cable, and a long, working-distance objective lens suitable for scanning through glass and thick-walled containers. The Basic package delivers what is needed for essential operation. The Mira DS Advanced package includes all elements of the Basic, plus a point-and-shoot adapter, right-angle sampling adapter, carrying case, USB power adapter (in addition to the included cable), laser safety glasses, microfiber cleaning cloth, and sampling blackout cloth. The Mira DS Flex also includes three separate point-and-shoot adapters for varying container types and thicknesses and a calibrate/verify accessory (CVA) that consists of a consists of an ASTM Raman shift standard and a NIST-traceable verification sample. Available enhancements also include a standoff attachment suitable for measuring samples up to 1.5m away, adapters for various containers, and surface enhanced Raman spectroscopy (SERS) capability.

A factory warranty of 18 months is included. Extended warranty and service maintenance programs that include instrument loan and 24/7 reachback support are also available for purchase.

4.6.1 Capability

The Mira DS received a Capability score of 3.5. The following information is based on evaluator comments:

- **Library:** The library met all the expectations of two evaluators, while four evaluators found it met most of their expectations. One evaluator found the library smaller than expected but appreciated that additional libraries could be purchased. Another evaluator noted that while the file names could be edited, users could not add notes.
- **Measurement Capabilities:** The Mira DS exceeded or met all expectations of the evaluators. Evaluators found the instrument worked quickly. (During the assessment, a maximum of 12 seconds for acquiring was observed). They also considered the standoff attachment useful for operations in the field.
- **Sample Identification Through Containers:** Half of the evaluators found the device met all their expectations for this criterion, while the other half found it met most of their expectations. Evaluators commented it was easy to navigate the container selection options. They had mixed experiences with sampling as one evaluator struggled with thicker containers, one said it did well with all container types and another found it to successfully measure through labels.
- **Multicomponent Measurements:** Two evaluators found the device met all of their expectations for multicomponent measurements, while four evaluators found it met most of their expectations. One evaluator was satisfied by the information the device provided, while another found it cumbersome to have to scroll to a second page to see confidence levels. One evaluator commented that the device was able to identify multiple components successfully, but they were not satisfied when the device reported “Flintstone vitamins” (Figure 4-23) when measuring mannitol, which is an ingredient in the vitamins.

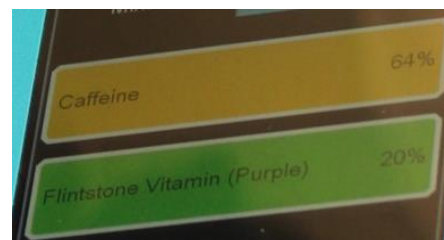


Figure 4-23 Metrohm Mira DS displaying sampling results

- **Reachback:** Four evaluators found reachback support met some of their expectations, because reachback does not extend passed the warranty without extra cost. Two found it met all their expectations as they were satisfied with the turnaround time of two hours for contact and 24 hours for analysis.
- **Sample Classification:** All evaluators found the device exceeded or met all their expectations for sample classification. Evaluators deemed the color-coding system useful and easy to interpret (i.e. red for illicit, yellow for questionable). They also appreciated that the instrument provides the GHS information as well as indicates whether the component is a cutting agent.
- **Data Export:** Most evaluators found the data export feature of the device met all their expectations; two found it met some. Evaluators noted that the device requires proprietary software and a USB cable for data export. One evaluator highlighted that the device provides results in PDF format while also providing access to the .spc file format. They also appreciated the option to use an Android mobile application to take photos to attach to the report.

4.6.2 Usability

The Mira DS received a Usability score of 3.7. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Evaluators had mixed feedback to the device's spectrum analysis tools. Three evaluators found it exceeded or met all of their expectations as the instrument allows users to reprocess data after adding a new library. They were also satisfied with the capabilities of the corresponding computer software. Three evaluators found it met most of their expectations, which they attributed to needing a computer to conduct spectrum analysis and the inability to zoom in on the overlay spectra on the instrument itself. Evaluators appreciated the device's capability to overlay spectra.
- **Ease of use:** Evaluators stated that all their expectations were met for this criterion, noting that the Mira DS has an intuitive interface, is easy to use for analysis and export, started up quickly, scanned quickly and detected vibrations. They also appreciated that the sleep mode is adjustable. Evaluators had difficulties selecting the proper sampling accessory and suggested the manufacturer provide a quick start guide.
- **Functionality with PPE:** All evaluators found the Mira DS met most of their expectations for functionality with PPE. Evaluators found the instrument's touchscreen responded while they were wearing dry and wet butyl gloves (Figure 4-24). One evaluator remarked it would not be usable with thick gloves; that is, while the keyboard can be operated with thin gloves on, hazmat PPE would not work. One evaluator suggested the manufacturer add buttons in addition to the touch screen to enhance usability.



Figure 4-24 Metrohm Mira DS being used while wearing gloves

- **Accessories:** Five evaluators found the accessories exceeded or met all their expectations; one found they met most of their expectations. Evaluators appreciated the number of sampling accessories available, but two evaluators noted that it may be difficult to choose from among the number of accessories or the number could be overwhelming to novice users. Evaluators voiced that the accessories integrated well with the device, but one evaluator raised concerns that the connection points to the accessories could wear off over time. Two evaluators noted that the Mira DS's attachment that enables a standoff feature would be useful in the field as well.
- **Administrative Controls:** The administrative controls of the device met all expectations for half of the evaluators and met most expectations for the others. The device offers one user level in the field, while administrative capabilities are performed from a computer using the software. One evaluator appreciated that the device is accessed via a PIN for up to six users (Figure 4-25).
- **Sample Labeling:** The sample labeling of the device met all expectations of the evaluators as it allows users to rename sample files and add notes to the sample spectra.



Figure 4-25 Metrohm Mira DS PIN entry screen

4.6.3 Deployability

The Mira DS received a Deployability score of 3.5. The following information is based on evaluator comments:

- **Durability:** The Mira DS met all durability expectations for two evaluators, and most expectations for four evaluators. One evaluator noted that the device having been tested to MIL-STD-810G specifications did not include a drop test. Other evaluators voiced concerns with the design of the protective boot: since a cracked screen would render the device unusable, they would have liked it to have had additional protection.
- **Decontamination:** Most evaluators found the device met most expectations for decontamination, noting concerns about the longevity of accessories (specifically their decay when exposed to saltwater), the lack of a plug or cover for the USB port and the number of crevices they observed on the device. Two evaluators found it exceeded their expectations based on the IP67 rating.
- **Power:** Evaluators gave mixed feedback related to power. The Mira DS exceeded expectations for two evaluators, as the instrument runs on commercial off-the-shelf (COTS) AA batteries and has a USB charging option. Three found it met most expectations, noting the lack of guidance for battery orientation, the inability to hot swap batteries, the need to purchase different battery types for the instrument and the standoff accessory (which takes a CR123), and difficulties they would expect to encounter if changing batteries while wearing gloves. One evaluator said it met some of their expectations, and attributed their rating to the expected rechargeable battery run time of one to two hours.

4.6.4 Maintainability

The Mira DS received a Maintainability score of 3.3. The following information is based on evaluator comments:

- **Calibration Requirements:** Evaluators had mixed feedback for calibration requirements (shown in Figure 4-26). Two evaluators found it exceeded, for two it met all o and for another two it met most of their expectations. Those who found it exceeded or met all expectations appreciated that the instrument used an ASTM standard to calibrate – not just a system check – and that the system notifies the user to add the calibration solution at startup. One evaluator raised their concern that the calibration accessory is not attached to the device and could therefore get lost and need to be repurchased at the cost of \$1,000. Two evaluators noted the calibration standard has an expiration that requires its periodically being replaced.



Figure 4-26 Metrohm Mira DS calibration phases

- **Consumables:** Four evaluators found the consumables for the instrument met some, one evaluator found they met most, and another found they met all of their expectations. Evaluators felt that accessory caps could get lost and therefore considered the caps a consumable. They also expressed concern that the SERS kit costs \$14 for one-time use with a limited shelf life of six months, and the suggested use of their vials (size of 15x26) which cost \$144 for 22 vials. The instrument also operates off of two AA batteries as well as a CR123 for standoff, which will be recurring purchases.
- **Warranty:** All evaluators found the warranty met most of their expectations. One evaluator commented that the two-year duration was sufficient but would have preferred that Metrohm had included the option to acquire a loaner instrument during repairs.

4.7 Smiths Detection ACE-ID

The Smiths Detection ACE-ID received an overall assessment score of 3.0 and costs \$27,000. The ACE-ID measures 5.0 x 3.0 x 2.2 inches and weighs 1 pound. The unit is powered by one COTS lithium-ion battery (SureFire or CR123A) or a USB power source. The ACE-ID has a class 3B 785 nm laser with an adjustable laser power up to 55 mW. It has an IP rating of 53 and meets MIL-STD-810G requirements. The unit can be operated at temperatures between -4 and 122 °F.

The unit has a touchscreen display that is compatible with gloves and other PPE and large buttons for one-handed use. The ACE-ID uses orbital raster scanning technology to diffuse the laser energy while collecting spectra from a larger area. This allows for a point-and-shoot method of sampling.



Figure 4-27 Smiths Detection ACE-ID

A spectral library of approximately 500 compounds including explosives, narcotics, and toxic chemicals is provided. Spectra can be added to instrument's library via software using a laptop. An integration software kit is available for remote operation and generating reports.

A one-year warranty is included with extended warranty options available for purchase. ReachBackID provides 24/7/365 reachback service for the unit.

4.7.1 Capability

The ACE-ID received a Capability score of 2.6. The following information is based on evaluator comments:

- **Library:** All evaluators found the library met only some of their expectations citing concerns that the standard library (at approximately 500 compounds) is too small for their purposes. Sample spectrum files cannot be tagged with informative metadata (e.g., "amber glass jar in suspect's basement").
- **Measurement Capabilities:** Half of the evaluators found the device met most of their expectations for measurement capabilities while the other half found it met some expectations. Two evaluators experienced user errors and another had difficulty seeing the focal point of the laser. One evaluator noted quick scan times with the device but would have preferred a setting to adjust laser power. Another commented that a beneficial addition to the ACE-ID would be a feature to display confidence level when identifying samples.
- **Sample Identification Through Containers:** Most evaluators found the device's ability to sample through containers met most of their expectations, while two found it met all their expectations. One evaluator noted that although the device was generally able to identify samples through containers, it was difficult to aim without being able to see the laser's focal point.
- **Multicomponent Measurements:** Half of the evaluators found the device met most of their expectations for multicomponent measurements, while the other half said it met some expectations. One evaluator commented that the ACE-ID's ability to identify both components of the mixture samples was inconsistent. Another added that the device provided only two compound identifications for samples with multiple components.
- **Reachback:** Reachback for the ACE-ID is available at a cost of \$10,000 per year. Two evaluators found the reachback support for the device met all their expectations. Four evaluators found it met most of their expectations, attributing their rating to their expectation that reachback support would come standard with the device or as part of a warranty. One evaluator highlighted that reachback is available 24 hours a day, seven days a week.



Figure 4-28 Evaluator sampling through an amber container using a Smiths Detection ACE-ID

- **Sample Classification:** Evaluators found the ACE-ID either met some or none of their expectations for sample classification. They would have preferred to see more information than just sample ID and CAS number. (Figure 4-29).
- **Data Export:** Two evaluators found the device met most and four, some of their expectations for data export. Proprietary software is required in order to open and view the data. One evaluator commented it would be cumbersome to convert the files to the “.spc” format in order to send the data to the manufacturer’s reachback support.



Figure 4-29 Smiths Detection ACE-ID sample classification

4.7.2 Usability

The ACE-ID received a Usability score of 3.3. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Half of the evaluators found the ACE-ID met most of their expectations, while the other half found that it met some of their expectations for spectrum analysis tools. These ratings were attributed to the limited onboard spectrum analysis capabilities as well as the inability to re-run an analysis without the command software.
- **Ease of Use:** Evaluators shared mixed feedback on ease of use. Two evaluators found the device exceeded expectations. Two found it met all expectations, noting that the device and button interface were intuitive, meanwhile two other evaluators said it met some of their expectations, having found the data export and the laptop interfaces difficult to operate.
- **Functionality with PPE:** Responses varied for this criterion. One evaluator found it exceeded their expectations, three found that it met all their expectations, and two, that it met most of their expectations. Two evaluators said they operated the device without issues while wearing butyl gloves, however one evaluator raised the concerns that it would be easy to inadvertently press the power button when gloved.
- **Screen Visibility:** Two evaluators found the screen exceeded their expectations (Figure 4-30); as all operations are done through the screen, they felt night operations would not be an issue. Most evaluators said the screen visibility met most of their expectations, noting the screen was smaller than they expected but still readable.
- **Accessories:** The device’s accessories met all the expectations of one evaluator and most expectations for the other five evaluators. One evaluator remarked that they were satisfied with the ruggedness of the case but concerned that the detachable vial holder could be easily lost .
- **Administrative Controls:** The ACE-ID met most of the expectations of two evaluators and some of the expectations of four evaluators.

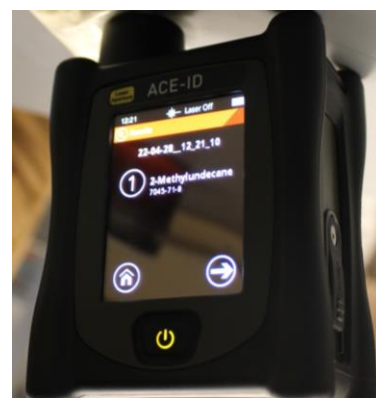


Figure 4-30 Smiths Detection ACE-ID displaying a detection of 2-Methylundecane

One evaluator found having only one level for the user limiting but added there is no risk of deleting data from the device once the right settings are established on a computer.

- **Sample Labeling:** Evaluators had mixed feedback on sample labeling. Two evaluators found it met most, three found it met some, and one evaluator said it did not meet any of their expectations. Four evaluators commented that needing to manually input the date and time when logging a sample could be a cumbersome process, one evaluator added it could lead to incorrect times being listed.

4.7.3 Deployability

The ACE-ID received a Deployability score of 3.2. The following information is based on evaluator comments:

- **Durability:** The durability of the ACE-ID met all the expectations of three evaluators while meeting some or most of the expectations of the other three. Two evaluators commented that the IP53 rating is lower than they expected and voiced concern about operating the device while wearing wet gloves. The IP53 rating raised similar concerns for the decontamination criterion as the device is not rated to be submersed in water. Nevertheless, two evaluators described the design as “rugged” and “sturdy.”
- **Power:** Evaluators were split evenly between finding the device met all versus most of their expectations for this criterion. They appreciated that the device ran on COTS batteries but were concerned about battery life. One evaluator commented that the battery swap was simple and easy, but another desired the ability to hot-swap the batteries.

4.7.4 Maintainability

The ACE-ID received a Maintainability score of 3.6. The following information is based on evaluator comments:

- **Calibration Requirements:** The device exceeded the expectations of three evaluators and met all or most expectations for the other three. The device automatically calibrates on start-up and calibration validation is built into the vial holder. Evaluators noted that the automatic calibration runs quickly.
- **Warranty:** The warranty met most of the expectations of all evaluators. The standard warranty is for one year, but evaluators valued the option to add years. One evaluator was disappointed/pointed out the standard one-year warranty does not provide loaner devices during repairs.

4.8 Serstech Arx

The Serstech Arx received an overall assessment score of 3.0 and costs approximately \$25,000–\$30,000. The Arx measures 5.9 x 3.3 x 1.1 inches and weighs 1.3 pounds. It is powered by a rechargeable internal battery that provides a runtime of 12 hours and can be also powered by plugging into an AC or DC power supply. The unit has a class 3B 785 nm invisible laser with an adjustable laser power up to 300 mW. The unit has an IP rating of 67, meets MIL-STD-810G and can be operated at temperatures between -4 and 122 °F.



Figure 4-31 Serstech Arx

Large, separated buttons allow the Arx to be used by operators wearing protective gloves. The Arx allows users to set the instrument to delay the start of the scan for up to 15 minutes, enabling them to exit a potentially hazardous area while the unit performs the scan. The unit also uses SharpEye, a patented autofocus technology that allows the device to autofocus on a target from 0 to 4 m away without the use of an adaptor. A spectral library of over 17,000 compounds covering explosives, narcotics, and hazardous materials is included. Target spectra can be added to instrument's library in the field but generating measurement reports and managing users and user-defined libraries are actions that must be performed using the computer software ChemDash. The device offers three options to export data to a computer: Bluetooth, Wi-Fi or USB.

Standard accessories included with the device include a vial holder, 90° angle adapter, watertight case, protective cap with calibration target, sample vials, and a USB cable for charging or connecting to a computer. An optional trace analysis SERS kit is available for an extra cost.

A five-year warranty is included with extended warranty options, up to 10 years, available for purchase. Serstech also provides 24 hours a day, seven days a week, 365 days a year reachback service.

4.8.1 Capability

The Arx received a Capability score of 2.5. The following information is based on evaluator comments:

- **Library:** Three evaluators found the library met some of their expectations and three found it met none. They stated that the standard library is insufficient as is, thus requiring users to add other libraries at additional cost. Also, users cannot add photos or comments. One evaluator highlighted the Arx does have the capabilities to select a library and create a custom library.
- **Measurement Capabilities:** Two evaluators said the Arx met most of their expectations for this criterion and four said it met some. One evaluator attributed their rating to the unit's lengthy analysis time, a delay at start-up and issues with identifying fluorescent samples. They also expressed concern that using the laser as heat could lead to damage or destruction of evidence. One evaluator appreciated the availability of a SERS kit.
- **Sample Identification Through Containers:** Five evaluators found the Arx met some of their expectations for this criterion, while one said it met none. Evaluators had issues when sampling fluorescents and in varied lighting. Some bags were damaged. Many identifications, especially of samples in dark plastic were missed. However, evaluators could see the device's laser focal point.
- **Multicomponent Measurement:** Five evaluators said the Arx met some of their expectations for multicomponent measurement, while one said it met none. The Arx did not correctly identify multicomponent samples, which is a critical function.
- **Reachback:** All evaluators said the Arx exceeded or met all of their expectations for reachback. Reachback is included with the 5-year warranty and is available 24 hours a day, seven days a week with a response time within 8 hours.



Figure 4-32 Sampling through an amber container using the Serstech Arx

- **Sample Classification:** Four evaluators said the Arx met most of their expectations, while two said it met some. The Arx has GHS, CAS numbers and sufficient color coding. Evaluators felt confidence levels were difficult to understand and would require more training. They noted there is no indication of potential pre-cursor materials (e.g., mannitol, caffeine, ammonium nitrate) and no warning about fluorescent samples.
- **Data Export:** Four evaluators said the Arx exceeded or met all of their expectations for data export. The Arx provides an extensive, editable, easy-to-generate generic report that includes standard history. It also provides encryption per Pharma practices as well as Bluetooth, Wi-Fi and USB export options. Two evaluators said it met some of their expectations, with one of them noting that the app for wireless data export is still under development.


4.8.2 Usability

The Arx received a Usability score of 3.1. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Two evaluators found the Arx met most of their expectations for spectrum analysis tools as users can overlay library spectra but only the identified compound is present. Four evaluators said it met some of their expectations, which they attributed to poor contrast on the display screen, and the overline spectra being the only feature for spectra analysis. They also cited the inability to zoom or see residuals. One evaluator appreciated that the font size was adjustable.
- **Ease of Use:** The Arx met most of the evaluators' expectations for ease of use. Evaluators felt the quick scan feature would be helpful during operations, the training and supplemental guides t useful and the user menu intuitive. However, the active laser warning remains on throughout processing, no lock is available for the laser, and the angled tip made positioning the device when sampling more difficult.
- **Functionality with PPE:** Five evaluators found the Arx meet all their expectations for functionality with PPE as the control buttons were large, tactile and spread out enough from one another to not impact their usability while the operator was wearing gloves. One evaluator said it met some of their expectations because they anticipate it would be difficult to read the screen through an SCBA mask.
- **Screen Visibility:** Evaluators had mixed feedback on screen visibility (Figure 4-33). Two evaluators found it met all of their expectations. Two said it met most, as the font and graphic colors used in the display diminished readability and contrast in brighter light environments. They did appreciate the user's ability to adjust font size. Two evaluators found it met some of their expectations, which they attributed to the buttons not being backlit, the display's resolution (which seemed low to them) and difficulties they had reading the screen due to glare.
- **Accessories:** Evaluators gave mixed feedback on the accessories available for the Arx. Two found it exceeded their expectations as the instrument comes with everything needed for operations, including a USB-C charger; they also appreciated that SERS is an option. Four evaluators found it met most or some of their expectations, citing concerns that the cap could be easily lost or damaged as well as disappointment at the lack of a mobile application.



Figure 4-33 Serstech Arx screen and buttons



Due to the smaller size of the Arx, one evaluator would have preferred the product to have a hardened rubber cover to enhance protection and alternate color options to enhance visibility.

- **Administrative Controls:** Three evaluators found the Arx exceeded or met all their expectations as different levels of user profiles are available. Three evaluators said it met most of their expectations, a rating they attributed to the lack of lock on the laser, and their uncertainty as to whether deleted information is recoverable. One evaluator highlighted the device's ability to assign libraries to specific users.
- **Sample Labeling:** All evaluators said the Arx met most or some of their expectations for sample labeling. They attributed these ratings to the lack of scale seen on the spectrum, which they deem as being necessary for providing an indication of where peaks are located. One evaluator would have preferred if the background for the spectrum were white. Additionally, files are saved by scan number, which can only be edited via software; one of the evaluators stated dates and times are needed as well. Another evaluator noted the inability for the user to add images or notes.

4.8.3 Deployability

The Arx received a Deployability score of 3.2. The following information is based on evaluator comments:

- **Durability:** Two evaluators said the durability of the Arx met all of their expectations, while four said it met most. The lack of a USB port cover, a desire for a more protective carrying case, and the heat transfer users felt when operating the spectrometer were cited as reasons behind the scores.
- **Decontamination:** Two evaluators said the ability to decontaminate the Arx met all of their expectations, while four found it met most. Evaluators cited exposed USB ports on the spectrometer that could be susceptible to contamination and corrosion had no seals or covers.
- **Power:** Evaluators had mixed feedback related to power. One evaluator said the Arx exceeded their expectations and one said it met all their expectations based on its 12-hour run time and the ability to charge it with any USB-C battery pack. Four evaluators said it met some of their expectations, which they attributed to the inability to hotswap the internal battery and the lack of a battery status indicator with a numerical value. (It is shown in bar format.) One evaluator highlighted the ability to use the spectrometer while it's charging and its three-hour charge time as advantages for operational use. Evaluators also viewed needing a special tool to open the battery compartment as a negative characteristic.

4.8.4 Maintainability

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

- **Warranty:** All evaluators found the warranty exceeded or met all their expectations. The Arx comes with a five-year warranty that can be extended to 10 years, at \$1,200 per year. The warranty includes repair through an authorized dealer or a next-day loaner as well as firmware updates throughout the lifetime of the spectrometer.

4.9 Pendar X10

The Pendar X10 received an overall assessment score of 2.9 and costs \$65,000–\$70,000. The Pendar X10 is 11.5 x 10.5 x 5.5 inches and weighs 6 pounds. The unit operates on CR123A batteries that provide a runtime greater than two hours. It has a ~830 nm laser with a maximum power of 90 mW. The Pendar X10 can be operated at temperatures between -4 and 104 °F.

The unit uses a single, one-handed press of a trigger to begin measurements and allows for use while wearing PPE. The Pendar X10 is a short-range standoff point-and-shoot system with measurement distances up to three feet. The Pendar X10 can also be mounted on a tripod for longer measurements. The Pendar X10 is a two-wavelength difference Raman system with the capability to measure highly fluorescent materials. It can measure dark and sensitive materials (e.g. gunpowder) without ignition. The provided library of 4,000 to 5,000 spectra includes explosives, TICs, and narcotics and can be expanded by the user. A one-year warranty is included in the list price with extended warranty options available at an additional cost.



Figure 4-34 Pendar X10

4.9.1 Capability

The Pendar X10 received a Capability score of 3.1. The following information is based on evaluator comments.

- **Library:** Evaluators gave mixed feedback on the Pendar X10’s library. Two evaluators found it met most of their expectations, while four said it met some or none of their expectations. Evaluators found the library small. Additional factors include a two month wait for library updates, users not being able to make additions to the library without support from Pendar, and no reference library of user spectra being available.
- **Measurement Capabilities:** Most evaluators found the Pendar X10’s measurement capabilities met all or most of their expectations. Evaluators attributed their ratings to the quick-moving laser point, its auto focus performance, the ability to measure at standoff distance (Figure 4-35), a “continue” option that enables the user to build 30 seconds onto the prior sample period, and the device’s being robot capable. One evaluator said the Pendar X10 met some expectations as the laser power was not adjustable and surface-enhanced Raman spectroscopy (SERS) kits were not available.



Figure 4-35 Pendar X10 being used for standoff measurement

- **Sample Identification Through Containers:** Four evaluators found the Pendar X10 's ability to identify samples through containers exceeded or met all of their expectations. Evaluators cited the ability to see the laser focal point, and both the autofocus and fine tune adjustments working well. Two evaluators said some of their expectations were met as it was difficult for them to adjust focal point with different container types.
- **Multicomponent Measurement:** All evaluators found the Pendar X10 met all or most of their expectations for multicomponent measurement. Evaluators were impressed with the results on the test samples, however one evaluator found it difficult to interpret the spectrum display.
- **Reachback:** Evaluators had mixed feedback related to reachback. Two evaluators found it met all their expectations and two stated it met most of their expectations. Two evaluators found it met some of their expectations because Pendar did not provide a timeframe for when a call would be returned. Additionally, evaluators noted that reachback is only available for instruments under warranty.
- **Sample Classification:** Five evaluators found the Pendar X10 met all or most of their expectations, while one found it met only some. Evaluators noted the device provides information quickly. It provides CAS numbers and the potential hazard of a sample is displayed prominently. Evaluators would have liked a warning for fluorescent samples and more color coding of other classes. Evaluators remarked that the scan time for florescent samples was lengthy.
- **Data Export:** Five evaluators found the Pendar X10 met all or most of their data export expectations as it provided the option to use a thumb drive or USB cable, as well as the ability to select only data that the user wants. One evaluator found it met some of their expectations and attributed their rating to their disliking the layout the exported data itself. The ability to overlay figures would have been a welcome additional capability.

4.9.2 Usability

The Pendar X10 received a Usability score of 2.9. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Four evaluators found the Pendar X10 met most of their expectations for spectrum analysis. Two found it met some, one of whom said the spectrum comparison was hard to decipher, noting that the user cannot overlay other spectra from the library with the sample spectrum and there was no indication of the quality of match. However, spectra could be overlaid on a laptop. Another evaluator would have liked to have been able to rerun the sample on the instrument.
- **Ease of Use:** The ease of use of the Pendar X10 met all or most expectations of five evaluators, while one said it met only some. They attributed their score to there not being a way for users to adjust the volume. One evaluator commented that the interface is sufficient, but additional controls could be included to prevent inadvertent operations. Another evaluator commented that the instrument requires a steady hand and good eyesight for good results. Another evaluator appreciated the X10's capability to continue a scan (Figure 4-36) and its more enhanced analysis, which tended to provide better quality

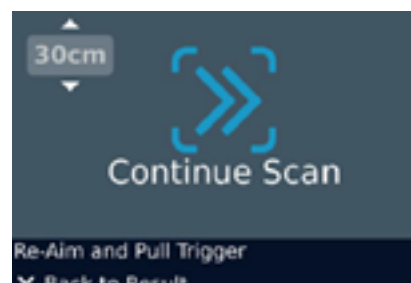


Figure 4-36 Pendar X10 “continue scan” screen

data or resolve multiple possible compounds. The autofocus capability was highly regarded by one evaluator.

- **Functionality with PPE:** Two evaluators said the Pendar X10 met all of their expectations noting it was very PPE friendly and usable with gloves. Four evaluators found it met most of their expectations as they experienced mixed results when using the touchscreen with gloves on.
- **Screen Visibility:** All evaluators found the screen visibility (Figure 4-37) met most or all of their expectations. However, evaluators recommended the manufacturer add a screen protector and the ability to change font sizes.
- **Accessories:** Four evaluators found the Pendar X10 met all or most of their expectations, while two said it met some expectations, noting that the stand case was too large. Another commented that the quick start guide was useful. Tripod options are available and robot integration is possible.
- **Administrative Controls:** Four evaluators found the administrative controls met some of their expectations, while two evaluators said the controls met none. The X10 has only one user level; evaluators were concerned that a basic user could delete data and clear the device's settings.
- **Sample Labeling:** Three evaluators found the sample labeling met some of their expectations. Three other evaluators said it met none of their expectations because there were no file names or numbers on the device (only time and date stamps) and users cannot add photos or notes.



Figure 4-37 Pendar X10 screen Scanning

4.9.3 Deployability

The Pendar X10 received a Deployability score of 2.4. The following information is based on evaluator comments:

- **Durability:** The durability of the Pendar X10 met some expectations of four evaluators and none of the expectations of two evaluators. One of the evaluators expressed concern that both the lens (Figure 4-38) and screen could be scratched (evaluators recommend that Pendar include a lens cap attachment to mitigate this risk), that humidity could cause fogging, that the usable temperature range is limited and that the unit was not tested to MILSPEC standards. (Testing to MIL-STD 810G was in-progress at time of the assessment.)
- **Decontamination:** The ability to decontaminate the Pendar X10 met all or most expectations of three evaluators as no special cleaning solutions are needed to decontaminate the device except for the lens.



Figure 4-38 Pendar X10 lens

Three evaluators found the X10 met some of their expectations, which they attributed to parts of the instrument being difficult to decontaminate such as the connections to the tripod mount's handle joint. Evaluators was also noted that the large lens could easily be smudged or smeared.

- **Power:** The Pendar X10 met all the expectations of this criterion for four evaluators as the battery is intuitive to change, rechargeable and external. A charger is included with purchase. The device can also run on USB-C power. Two evaluators said the device met some or none of their expectations, which they attributed to poor design of the battery door and a battery life that is too short (two hours per battery).

4.9.4 Maintainability

The Pendar X10 received a Maintainability score of 3.1. The following information is based on evaluator comments:

- **Calibration Requirements:** All evaluators found the Pendar X10 met all or most of their expectations as it does not need calibration but may require a verification polystyrene to confirm accuracy of results.
- **Consumables:** The Pendar X10 exceeded expectations of four evaluators, who remarked on its coming with extra rechargeable batteries and not requiring additional consumable items. Two evaluators found it met some of their expectations as they raised the concern that replacement batteries could be a cost factor.
- **Warranty:** Two evaluators found the warranty for the device met most of their expectations, while four evaluators found it met some. Most evaluators commented that a one-year standard warranty is a short time, and the \$6,500 cost is higher than they expected.

4.10 Chemring PGR-1064

The Chemring PGR-1064 received an overall assessment score of 2.8 and costs \$32,500. The PGR-1064 measures 2.5 x 7.5 x 6.6 inches and weighs 2.25 pounds. The unit has a rechargeable lithium-ion three-cell pack battery with a 10+ hour runtime. A CR123A battery pack option is also available. It has a class 3B 1064 nm laser with an adjustable laser up to a power of 500 mW. The unit has an IP rating of 66 and is MIL-STD 810G-compliant for shock and vibration. The PGR-1064 can be operated at temperatures between -4 and 104 °F.

The PGR-1064 has a guided workflow provided on the display screen. A joystick and trigger operation allow for one-handed use. A customizable library of more than 5,000 compounds is included; it consists of explosives, fuels, synthetic and prescription drugs, cutting agents, chemical warfare agents, TICs, common household chemicals, and narcotics, including fentanyl.

A one-year warranty is included with extended warranty options available for purchase.

4.10.1 Capability

The PGR-1064 received a Capability score of 2.4. The following information is based on evaluator comments:



Figure 4-39 Chemring PGR-1064

- **Library:** Evaluators had mixed feedback on the library. Two evaluators found the library met all of their expectations, while four said it met some or none of their expectations. The less satisfied evaluators attributed this to the limited size of the library (which included 5,000 compounds and 100 drug-related compounds) and that the library allows only limited updates.
- **Measurement Capabilities:** Four evaluators found the PGR-1064 met some of their expectations for measurement capabilities, while two said it met most. Evaluators noted it was time consuming to adjust focal point length and that it was not possible to adjusting it in a no-light setting.; they also expressed concern that training for focal point adjustment would be challenging. Evaluators experienced difficulties identifying fluorescent samples and handling the instrument due to its gun-shaped form factor (Figure 4-40), which was not convenient for some sampling positions.



Figure 4-40 Chemring PGR-1064 being used to sample through an amber container

- **Sample Identification Through Containers:** Four evaluators found the PGR-1064 exceeded or met all of their expectations for this criterion. One evaluator for whom the device exceeded expectations commented that it worked well with various containers; the focal length adjustment was easy; and liked that the yellow, green, red "SCAN ID" box indicated the level of confidence. Two evaluators found the unit met some or none of their expectations citing that the focal point accessibility is difficult.
- **Multicomponent Measurement:** Four evaluators found the device met most of their expectations. Two found it met none as the PRG-1064 did not properly identify components of mixtures and repeatedly provided inconsistent results when these evaluators used it.
- **Reachback:** Evaluators found reachback met either some or none of their expectations. These ratings were attributed to reachback being provided only while the instrument is under warranty as well as the limited access to reachback personnel and limited hours of operation (which are only during standard business hours).
- **Sample Classification:** All evaluators found the sample classification of the PRG-1064 met some or none of their expectations. This was attributed to the instrument providing an identifier for the quality of scan but no supplementary information such as CAS numbers. Evaluators would also have liked to see warnings if the material is hazardous or explosive.
- **Data Export:** All evaluators said the PGR-1064 met some of their expectations for data export, which they attributed to the instrument taking a significant amount of time to recall files, the need for proprietary software, the lack of residual analysis, and the reports being limited in information to simple spectra and predominant compound.

4.10.2 Usability

The PGR-1064 received a Usability score of 2.7. The following information is based on evaluator comments:

- **Spectrum Analysis Tools:** Four evaluators found the PGR 1064 met some of their expectations for spectrum analysis, and two found it met none. Evaluators attributed their scores to the inability to overlay the sample and library spectra, inability to use .spc files to transfer data to another system and the screen being too small to effectively compare results.
- **Ease of Use:** Evaluators had mixed reviews for the ease of use of the PGR-1064 with two saying it met all expectations, two saying it met most and two saying it met some. Those who said it met some of their expectations attributed their rating to the analyses taking more time than the vendor-provided duration estimates and the lack of explanation for focal point adjustments. Evaluators who said it met most of their expectations experienced difficulties with positioning and adjusting the focal length in low lighting. Evaluators also noted that the rings on the nose cone did not correlate to the depth of focal length, making it unclear what the setting was. One evaluator highlighted that the buttons were easy to use.

- **Screen Visibility:** Evaluators found screen visibility met most or some of their expectations (Figure 4-41). Evaluators said the screen was bright enough to be seen in the dark, however they deemed screen itself and the font size (which cannot be adjusted) too small.




Figure 4-41 Chemring PGR-1064 screen display

- **Accessories:** Evaluators found this met most or some of their expectations, as there were minimal accessories to account for. One evaluator disliked the large size of carrying case citing limited space in response vehicles.
- **Administrative Controls:** Two evaluators said the PGR-1064's the administrative controls met all their expectations, while four evaluators said they met some of their expectations. Evaluators attributed this rating to the laser arm being password protected, the limitation of only one library being available to the field user and the inability to change the library. One evaluator suggested the manufacturer include the ability to customize user levels.
- **Sample Labeling:** Four evaluators found the sample labeling met none of their expectations as the file names were very long, notes could only be added using proprietary software, and files had to be transferred to computer before you could change their file names. However, two evaluators stated it met most of their expectations as they found the automatically generated filename with the time and date and the automatically added meta data helpful.

4.10.3 Deployability

The PGR-1064 received a Deployability score of 3.3. The following information is based on evaluator comments:

- **Durability:** The durability of the PGR-1054 met most or all expectations of the evaluators as the USB port and power output were well covered. Evaluators noted that the screw top laser focal point appeared to be loose and expressed concern about its getting lost.

- 
- **Decontamination:** The ability to decontaminate the PGR-1064 met all or most of the expectations of two evaluators. All ports were covered, and the device only needs to be wiped for decontamination. Four evaluators found that it only met some of their expectations saying there were a lot of crevices, and the device could not be dunked in a decontamination solution.

4.10.4 Maintainability

The PGR-1064 received a Maintainability score of 3.5. The following information is based on evaluator comments:





- **Calibration Requirements:** All evaluators found the PGR-1064 met or exceeded all their expectations for calibration requirements as the device needs only to be validated with polystyrene.
- **Consumables:** The PGR-1064 exceeded expectations for two evaluators, met all expectations for two evaluators, and met most expectations for two evaluators on this criterion. They noted that the consumables are easily available and easy to maintain as any vials can be used.

5.0 SUMMARY







Table 5-1 summarizes the advantages and disadvantages for each product as identified by the evaluators.

Individual responder agencies that intend to purchase handheld Raman spectrometers should carefully research the capabilities and features of available instruments to identify the product best suited to their operational needs.

Table 5-1 Product Advantage and Disadvantages

Manufacturer/Product		Advantages	Disadvantages
	Agilent Resolve	<ul style="list-style-type: none"> Measures through opaque plastic containers Large, spread-out buttons easy to use with heavy gloves Backlit buttons and fairly large, clear screen with good color contrast Display auto rotates/resizes 	<ul style="list-style-type: none"> Proprietary batteries Batteries are not hot-swappable Users cannot add notes to sample spectra Includes warranty is only one year
MSRP: \$65-72k	Overall Score: 4.3		
	Thermo Scientific Gemini	<ul style="list-style-type: none"> All libraries included with purchase (no additional cost) Large buttons/Easy to use with heavy gloves Sample and library spectra can overlay on screen Small number of accessories simplifies operation 	<ul style="list-style-type: none"> Does not have a true calibration, only a check sample Included warranty is only a one-year Reachback is only for instruments under warranty
MSRP: \$105-134k	Overall Score: 4.2		
	Thermo Scientific First Defender RMX	<ul style="list-style-type: none"> Ability to expand screen enhances visibility Easy to use with heavy gloves Focal point controlled without needing an accessory 	<ul style="list-style-type: none"> Buttons aren't backlit except for arming and quick scanning Secure Digital (SD) card is difficult to remove Included warranty is only one-year Reachback is only for instruments under warranty
MSRP: \$64-80k	Overall Score: 4.0		
	Rigaku ResQ CQL	<ul style="list-style-type: none"> Large buttons/Easy to use (only two buttons really needed) Touchscreen easy to use with heavy gloves Screen visibility good at off angles and in low/high lighting 	<ul style="list-style-type: none"> Option to change file names is useful for some disciplines (firefighters) but not others (law enforcement) Crevices may complicate instrument decontamination
MSRP: \$46k	Overall Score: 3.9		



Manufacturer/Product		Advantages	Disadvantages
 <p>B&W Tek TacticID-1064</p>		<ul style="list-style-type: none"> • Extensive list of narcotics in the library • Option to add notes and photos • Spectra overlay on screen, can zoom • Multiple accessories for different sample containers 	<ul style="list-style-type: none"> • Buttons too small to use with heavy gloves • User cannot change spectra file names • Requires user to switch windows to see the scan ID and % match
	MSRP: \$44.5k		
 <p>Metrohm Mira DS</p>		<ul style="list-style-type: none"> • All results can be displayed in one window • Spectra overlay on screen • Several sample adapters are available • Warranty covers calibration standard replacement 	<ul style="list-style-type: none"> • Difficult to use with heavy gloves • No zoom or other manipulation of on-screen spectra overlay • No cover for USB port • Reachback is not included with standard warranty
	MSRP: \$30.7k+		
 <p>Smiths Detection Ace-ID</p>		<ul style="list-style-type: none"> • Quick validation/startup • Easy to use with heavy gloves • Spectral results displayed in one window • Minimal crevices suggest ease of decontamination 	<ul style="list-style-type: none"> • Small screen with small font • No screen rotation • Extremely limited library size • Requires proprietary software to open/view data • No USB • Reachback is not included with standard warranty
	MSRP: \$27k		
 <p>Serstech Arx</p>		<ul style="list-style-type: none"> • Large buttons, easy to use with heavy gloves • USB charging capability • Easy to generate reports • Five-year warranty 	<ul style="list-style-type: none"> • Slow startup and analysis • Poor screen contrast • Users cannot add notes to spectra • Limited spectral analysis capabilities
	MSRP: \$25–30k		
 <p>Pendar X10</p>		<ul style="list-style-type: none"> • Easy to use with heavy gloves • Identifies mixture samples well • Data export via USB (cable or drive) • Tripod option available • Robot integration possible 	<ul style="list-style-type: none"> • Standoff measurement mode only • No zoom for spectral analysis on instrument • Difficult to correctly adjust the focal point for different containers • Difficult to maintain steady focus with the laser
	MSRP: \$65–70k		
 <p>Chemring PGR-1064</p>		<ul style="list-style-type: none"> • Can be operated with heavy gloves • Screen visible in the dark • USB port 	<ul style="list-style-type: none"> • Small screen • Difficult to adjust focal point, especially in the dark • Gun-shaped form factor inconvenient for some samples/hard to position • Slow file recall
	MSRP: \$32.5k		



6.0 ACKNOWLEDGEMENTS

NUSTL thanks the assessment evaluators for their valuable time and expertise. Their insights and recommendations will assist responder agencies making procurement decisions and guide the planning and execution of future SAVER projects. Appreciation is also extended to the Baltimore County (Maryland) Fire Department, Department of Homeland Security's U.S. Customs and Border Protection Office (New Jersey), District of Columbia Fire and Emergency Medical Services Department, New Jersey State Police, Seattle (Washington) Fire Department, and the Southern Manatee (Florida) Fire and Rescue District for allowing the evaluators to participate in this SAVER assessment.



7.0 REFERENCES

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APPENDIX A. EVALUATION CRITERIA DEFINITIONS

The focus group identified 20 criteria, which they defined as follows.

CAPABILITY

Library refers to manufacturer-provided or user-created spectrum libraries.

Factors to consider: Inclusion of references to Chemical Abstracts Service numbers, ability to customize spectral libraries to include spectra of significant sample types that users have encountered and to tag spectrum files with informative metadata (i.e., a descriptive text linking a user-collected spectrum to an event).

Measurement Capabilities refers to sample analysis capabilities.

Factors to consider: Laser interrogation features (e.g., raster or broad beam scanning; the ability to see where the laser focal point is aimed), the availability and effectiveness of surface-enhanced Raman spectroscopy (SERS) options, standoff measurement capability, the ability to delay the start of analysis, fluorescence compensation capabilities; the minimum measurable sample size, and whether a sample vial holder is provided.

Sample Identification through Containers refers to the ability to analyze samples in container types commonly encountered during field operations.

Factors to consider: Sample identification in various container types that the focus group reported encountering frequently, including clear and colored glass, opaque and semi-opaque containers, plastic bags, gel caps, wax-paper envelopes, and regular paper envelopes. Relevant instrument features mentioned by the focus group were laser wavelength, laser focal point adjustability and the ability to see/aim the laser focal point.

Multicomponent Measurement refers to the ability to identify the chemical composition of samples containing a mixture of two or three major components.

Factors to consider: Spectrum analysis software features related to multicomponent sample analysis, such as spectral subtraction.

Reachback refers to technical support provided by the instrument manufacturer to assist responders in correctly identifying analytically challenging samples.

Factors to consider: The technical quality of the analysis results provided, the turnaround time for analysis of submitted data, schedule of reachback availability (e.g., provided on a 24/7/365 basis versus normal business hours), and the cost of reachback service options.

Sample Classification refers to whether analysis results provide supplementary information that is useful in interpreting and acting on analysis results.

Factors to consider: Examples of useful supplemental information cited by the focus group were an indication of the chemical compound class identified (e.g., hydrocarbon or protein), whether identified compounds are hazardous (e.g., explosive) and whether the sample is highly fluorescent.

Data Export refers to options provided for exporting acquired data from the instrument and the suitability of instrument-generated reports for use by the responder organization (e.g., by incident command).

Factors to consider: Cable and wireless data export options, ability for acquired data to be monitored and analyzed in real-time from a remote location. Additional factors cited were data security and encryption options, the range of data file types that can be created, and the thoroughness and clarity of instrument-generated analysis reports.



USABILITY

Data Analysis refers to features of the spectrum analysis software, both onboard the instrument and manufacturer-provided software running on an external laptop computer.

Factors to consider: The ability to view sample spectra overlaid on reference library spectra to judge the degree of match. The focus group indicated that being able to effectively compare sample spectra to library spectra using just the instrument's user interface rather than transferring the spectra to a laptop is often desirable.

Ease of Use refers to the general ease of operating the instrument.

Factors to consider: Whether the user interface is intuitive to navigate, whether the instrument operating software guides users through sample analysis steps, whether user manuals or quick start guides are helpful and can be viewed on the instrument's display screen. The focus group recommended that instrument start-up and sample analysis times be determined as part of this evaluation criterion.

Functionality with Personal Protective Equipment (PPE) refers to how effectively the instrument can be operated while wearing PPE.

Factors to consider: Ease and effectiveness of instrument operation while wearing typical protective gear. Typical hand protection would be heavy rubber hazmat gloves or structural firefighting gloves with nitrile gloves worn underneath. and a typical facial protection is a Level A hood.

Screen Visibility refers to the readability of the instrument display screen and related controls.

Factors to consider: Display screen readability in bright daylight or in darkness, whether manually operated buttons are backlit, and whether users can adjust display screen font sizes.

Accessories refers to the usefulness of accessories evaluated at the assessment.

Factors to consider: The instrument carrying case, sample interrogation accessories, sample vial holders, and data cables provided with the instrument.

Administrative Controls refers to the ability to limit access to certain instrument features based on user experience level.

Factors to consider: Availability of advanced and basic user-level modes, and which instrument control settings and library features are inaccessible in basic user mode.

Sample Labelling refers to the ability to assign descriptive file names to acquired data files.

Factors to consider: Ability for acquired spectrum files to be saved with names and supplementary comments that aid in later finding them and understanding the nature of the analyzed sample.

DEPLOYABILITY

Durability refers to how well the instrument is designed to withstand damage during use, storage, and decontamination.

Factors to consider: Instrument compliance to standards such as U.S. military drop and vibration standards (i.e. MIL-STD 810G) and Ingress Protection (IP) ratings for water and dust resistance. Also, suitability of instrument operating and storage temperature ranges for field conditions, and the protection provided by the instrument storage case.

Decontamination refers to how easily and effectively the instrument can be decontaminated.

Factors to consider: IP rating, presence of hard-to-clean crevices on external surfaces, and whether special tools are needed to clean the instrument.



Power refers to the suitability of internal and external power sources.

Factors to consider: Instrument operating time on battery power both when idle and in active use, whether batteries are 'hot swappable' (i.e., they can be replaced without turning the instrument off), availability of batteries in stores versus special order, and ease of battery change-out in the field. Also, whether a device has external 12-volt direct current or 120-volt alternating current power options.

MAINTAINABILITY

Calibration Requirements refers to long- and short-term requirements for instrument calibration.

Factors to consider: Ease and speed of field calibration, and the manufacturer-recommended factory calibration schedule.

Consumables refers to replaceable components needed for ongoing instrument operation.

Factors to consider: The cost, availability and suitability of necessary consumables such as sampling kits, sample vials, and calibration check samples.

Warranty refers to the terms of the instrument warranty offered by the manufacturer.

Factors to consider: The availability of loaner instruments.

APPENDIX B. ASSESSMENT SCORING FORMULA

The overall assessment 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 criterion weight assigned by the focus group, thus resulting in a weighted criterion rating. 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

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

Category Score Example ^{iv}

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

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 Assessment Score Formula

$$\sum(Category\ Score \times Category\ Percentage) = \text{Overall Assessment Score}$$

Overall Assessment Score Example

<u>Capability</u>	<u>Usability</u>	<u>Affordability</u>	<u>Maintainability</u>	<u>Deployability</u>	
(4.0 × 33%)	+	(4.2 × 27%)	+	(4.2 × 20%)	+
		(3.8 × 13%)	+	(4.5 × 7%)	= 4.1

^{iv} Examples are for illustration purposes only. Formulas vary depending on the number of criteria and categories assessed and the criteria and category weights