



System Assessment and Validation for Emergency Responders (SAVER)

Portable Infrared Spectroscopy Chemical Detectors Assessment Report

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System Assessment and Validation for Emergency Responders

Prepared by Pacific Northwest National Laboratory

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FOREWORD

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

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

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: “What equipment is available?” and “How does it perform?” These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. As a SAVER Program Technical Agent, Pacific Northwest National Laboratory (PNNL) has been tasked to provide expertise and analysis on portable Fourier transform infrared spectroscopy chemical detectors (FTIR). In support of this tasking, PNNL developed this report to provide emergency responders with information obtained from an operationally oriented assessment of FTIRs, which fall under the following AEL reference numbers:

- 07CD-01-FTIR, Fourier Transform Infrared, Point, Chemical Agent
- 07ED-01-IREN, Detector, Explosive, Infrared Spectroscopy.

For more information on the SAVER Program or to view additional reports on FTIRs or other technologies, visit www.dhs.gov/science-and-technology/SAVER.

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EXECUTIVE SUMMARY

Portable Fourier transform infrared spectroscopy chemical detectors (FTIR) are widely used by first responders to identify unknown or suspect materials. Applications include chemical spills, suspicious substance/package screening, clandestine labs, illegal dumping sites, arson investigations, and unlabeled containers or drums. FTIRs may be used in combination with other technologies (e.g., photoionization detectors) to improve confidence in detection and/or identification.

In April 2016, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of portable FTIRs.

Six portable FTIRs were assessed by emergency responders. The criteria and scenarios used in this assessment were derived from the results of a focus group of emergency responders with experience using portable FTIRs. The assessment addressed 11 evaluation criteria in 4 SAVER categories: 1) Capability, 2) Deployability, 3) Maintainability, and 4) Usability. The overall results of the assessment are highlighted in the following table.

| Product | Overall Score | Overall | Usability | Deployability | Capability | Maintainability |
|--|---|---------|-----------|---------------|------------|-----------------|
| Thermo Scientific™ Gemini™ Analyzer | | 4.0 | 4.0 | 4.1 | 3.9 | 4.0 |
| Thermo Scientific™ TruDefender™ FTXi | | 4.0 | 3.9 | 4.1 | 4.1 | 4.0 |
| Smiths Detection HazMatID™ Elite | | 4.0 | 3.9 | 4.1 | 4.1 | 4.0 |
| Agilent Technologies 4500 Series Portable FTIR | | 3.5 | 4.0 | 3.0 | 2.3 | 3.6 |
| Smiths Detection HazMatID™ 360 | | 3.4 | 3.4 | 3.2 | 3.6 | 3.1 |
| | Least Favorable Most Favorable | | | | | |

1. INTRODUCTION

Portable Fourier transform infrared spectroscopy chemical detectors (FTIRs) are widely used by first responders to identify unknown or suspect materials. Applications include chemical spills, suspicious substance/package screening, clandestine labs, illegal dumping sites, arson investigations, and identification of unlabeled containers or drums. FTIRs may be used in combination with other technologies (e.g., photoionization detectors) to improve confidence in detection and/or identification.

In April 2016, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of portable FTIRs. The purpose of this assessment was to obtain information on FTIRs that will be useful in making operational and procurement decisions. The activities associated with this assessment were based on recommendations from a focus group of emergency responders with experience using portable FTIRs.



Figure 1-1. Responders Participating in the Assessment Process

1.1 Evaluator Information

Seven emergency responders from various jurisdictions and with at least seven years of experience using FTIRs were selected to be evaluators for the assessment. Evaluator information is listed in Table 1-1. Prior to the assessment, evaluators signed a nondisclosure agreement, conflict of interest statement, and photo release form.

Table 1-1. Evaluator Information


| Participant | Years of Experience | State |
|--|---------------------|-------|
| Fire Services, Hazmat Technician (retired) | 20+ | FL |
| Fire Services, Assistant Fire Chief and Hazmat Coordinator | 20+ | IL |
| Fire Services, Firefighter and Hazmat Technician | 20+ | MI |
| Fire Services, Firefighter and Hazmat Technician | 20+ | WA |
| Fire Services, Special Operations | 11-15 | MD |
| National Guard, Civil Support Team | 6-10 | GA |
| Army, Industrial Hygienist | 6-10 | MD |



1.2 Assessment Products

Six products were selected and provided on loan from the vendors for the assessment based on market research and the focus group's recommendations. Focus group participants did not provide any product selection criteria and suggested an assessment of all currently available portable FTIRs if time permitted. If fewer FTIRs needed to be assessed because of time constraints, the focus group recommended selecting no more than two instruments from each of the three known vendors: Agilent Technologies, Smiths Detection, and Thermo Scientific. To limit scope, FTIRs that are primarily designed to detect only gases or illicit drugs were deemed outside the scope of the assessment. It is important to note that the Agilent 4300 Handheld FTIR is not designed for use in hazardous environments (e.g., hot zones) or while wearing personal protective equipment and it is not marketed to emergency responders. Therefore, the assessment results for the Agilent 4300 Handheld FTIR have been separated from the other products and are provided in Appendix A. Only evaluator comments, not scores, are provided in Appendix A.

Table 1-2 identifies the products that were assessed.

Table 1-2. Assessed Products

| Vendor | Product | Product Image |
|----------------------|---------------------------------|---|
| Agilent Technologies | 4300 Handheld FTIR ¹ |  |
| | 4500 Series Portable FTIR |  |
| Smiths Detection | HazMatID™ 360 |  |
| | HazMatID™ Elite |  |

| Vendor | Product | Product Image |
|---|-------------------------------|---|
| Thermo Scientific™ | Gemini™ Analyzer ² |  |
| | TruDefender™ FTXi |  |
| <p>Notes:</p> <p>¹ The 4300 Handheld FTIR is not designed for use in hazardous environments (e.g., hot zone) or while wearing personal protective equipment and it is not marketed to emergency responders. Evaluator assessment comments are provided in Appendix A.</p> <p>² Includes both FTIR and Raman spectroscopy; only FTIR spectroscopy capability was assessed.</p> | | |

2. EVALUATION CRITERIA

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

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

The focus group of emergency responders met in September 2015 and identified 11 evaluation criteria within 4 SAVER categories: 1) Capability, 2) Deployability, 3) Maintainability, and 4) Usability. They assigned a weight for each criterion's level of importance on a scale of 1 to 5, with 1 being somewhat important and 5 being of utmost importance. The SAVER categories were assigned a percentage to represent each category's importance relative to the other categories. The focus group discussed the Affordability category but did not identify any evaluation criteria for that category.

Products were assessed against 13 evaluation criteria. Table 2-1 presents the evaluation criteria and their associated weights as well as the percentages assigned to the SAVER categories. Refer to Appendix A for evaluation criteria definitions.

Table 2-1. Evaluation Criteria

| SAVER CATEGORIES | | | |
|--|-------------------------------------|--------------------------------|---|
| Usability | Deployability | Capability | Maintainability |
| Overall Weight 55% | Overall Weight 35% | Overall Weight 7% | Overall Weight 3% |
| Evaluation Criteria | | | |
| Sample Preparation/ Data Acquisition Weight: 5 | Ease of Setup Weight: 4 | Durability Weight: 4 | Ease of Maintenance Weight: 2 |
| User Interface Weight: 4 | Decontamination Weight: 4 | | |
| Results Interpretation Weight: 4 | Power Options Weight: 4 | | |
| Display Characteristics Weight: 3 | Portability Weight: 3 | | |
| Data Transfer Weight: 3 | | | |

3. ASSESSMENT METHODOLOGY

The products were assessed over three days. On the first day of the assessment, facilitators and a subject matter expert presented a safety briefing and an overview of the assessment process, procedures, and schedule. Specification assessments for all six products were completed on the first day. On each of the next three days, a different vendor brought two different FTIRs (two of each type of FTIR). The vendor conducted training and product familiarization, and then the operational assessments were conducted by the evaluators on that vendor’s FTIRs.



Figure 3-1. Vendor Training and Product Familiarization



Figure 3-2. Data Acquisition Assessment in Bright Light (Simulated Sunlight) and Low Light

3.1 Phase I. Specification Assessment

During the specification assessment, evaluators assessed each product based on vendor-provided information and specifications. Product information was confirmed by vendors prior to the assessment and any questions that evaluators had after the first day specification assessment were presented to specific vendors on the day they were present.

3.2 Phase II. Operational Assessment

During the operational assessment, evaluators assessed each product based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. The vendors assisted the evaluators with product familiarization, and evaluators had access to the reference material included with each product. The products were assessed in the following three scenarios: 1) setup scenario, 2) portability and data acquisition scenario, and 3) wrap-up scenario. Evaluators used the products one at a time and completed the assessment worksheets for each product before assessing the next product.

3.2.1 Setup Scenario

During the setup scenario, evaluators worked in pairs and were not in personal protective equipment (PPE). Evaluators inspected the sturdiness of the controls and determined if the detectors featured covered ports and/or sealed battery compartments (Durability). Next, evaluators prepared the detectors to take sample measurements based on vendor-provided instructions in user manuals (Ease of Setup).

3.2.2 Portability and Data Acquisition Scenario

During the portability and data acquisition scenario, evaluators wore PPE (i.e., Level A HazMat encapsulating jacket with a self-contained breathing apparatus facepiece and inner and outer gloves). The following stations were part of this scenario.

- *Station 1, Portability, Normal Light:* To assess Portability, evaluators carried each detector 75 feet, which included a flight of stairs.
- *Station 2, Liquid Sample Measurement, Bright Light:* This station was located indoors in a room under a 400 Watt metal halide lamp to simulate glare from the sun. The evaluator collected a mineral oil sample located on a table using a disposable dropper, placed the sample on the detector, and ran the analysis (Sample Preparation/Data Acquisition). Evaluators also assessed the readability of the labels on the buttons/controls (User Interface) and the readability, size, contrast, resolution, and backlight of the display (Display Characteristics).
- *Station 3, Solid Sample Measurement, Low Light:* This station was located in a dark room and evaluators were able to use a flashlight held by a co-responder while working. They collected a powdered egg sample located on a table using a sampling tool, placed the sample on the detector, and ran the analysis (Sample Preparation/Data Acquisition). Evaluators also assessed the readability of the labels on the buttons/controls (User Interface) and the readability, size, contrast, resolution, and backlight of the display (Display Characteristics).



Figure 3-3. Portability Assessment

3.2.3 Wrap-Up Scenario

During the wrap-up scenario, evaluators were not in PPE.

- *Station 1, Results Interpretation and Data Transfer, Normal Light:* To assess Results Interpretation, evaluators reviewed the spectra collected at one of the portability and data-acquisition scenario stations. They assessed the ease of interpreting the analysis results, used spectral processing options (e.g., spectral subtraction, mixture analysis/residual spectra display) to further analyze the results, and noted the quality of the spectrum (e.g., signal-to-noise, spectral resolution). Then, evaluators followed steps provided in the user manual to prepare a spectrum for transfer to the vendor for reachback support, but did not actually transfer the data to the vendor (Data Transfer).



Figure 3-4. Results Interpretation and Data Transfer Assessment

- *Station 2, Decontamination, Ease of Maintenance, and Durability, Normal Light:* Evaluators reviewed the vendor-provided decontamination steps and list of solutions approved for decontamination of the detectors while inspecting the detectors to assess Decontamination. Then, they cleaned the detectors based on vendor recommendations provided in the user manuals and replaced/charged the batteries in the detectors to assess Ease of Maintenance. Once the detectors were assessed for Decontamination and Ease of Maintenance, evaluators inspected the detectors to determine if any damage occurred during the assessment to assess Durability.



Figure 3-5. Decontamination, Ease of Maintenance, and Durability Assessment

3.3 Data Gathering and Analysis

Each evaluator was issued an assessment workbook that contained vendor-provided information and specifications, assessment procedures, and worksheets for recording criteria ratings and comments. Evaluators used 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* of my expectations for this criterion
5. The product *exceeds* my expectations for this criterion.

Criteria that were rated multiple times throughout the assessment were assigned final overall ratings by the evaluators. Facilitators captured advantages and disadvantages for the assessed products as well as general comments from the FTIR assessments and the general process for technology assessment. Once assessment activities were completed, reviewed their criteria ratings and comments for all products and made adjustments as necessary.

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

4. ASSESSMENT RESULTS

Overall scores for the assessed products ranged from 3.4 to 4.0. 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. Calculation of the overall score uses the raw scores for each category, prior to rounding; products with the same rounded overall score are in order based on the raw data.

Table 4-1. Assessment Results

| Product | Overall Score | Overall | Usability | Deployability | Capability | Maintainability |
|--|-----------------|----------------|-----------|---------------|------------|-----------------|
| Thermo Scientific™ Gemini™ Analyzer | | 4.0 | 4.0 | 4.1 | 3.9 | 4.0 |
| Thermo Scientific™ TruDefender™ FTXi | | 4.0 | 3.9 | 4.1 | 4.1 | 4.0 |
| Smiths Detection HazMatID™ Elite | | 4.0 | 3.9 | 4.1 | 4.1 | 4.0 |
| Agilent Technologies 4500 Series Portable FTIR | | 3.5 | 4.0 | 3.0 | 2.3 | 3.6 |
| Smiths Detection HazMatID™ 360 | | 3.4 | 3.4 | 3.2 | 3.6 | 3.1 |
| | Least Favorable | Most Favorable | | | | |

Table 4-2 presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. Evaluation criteria definitions are provided in Appendix A. Table 4-3 presents vendor-provided key specifications for the assessed products.

Table 4-2. Criteria Ratings

| KEY | | | | | | |
|------------------------|---|------------------|-------------------|-----------------|---------------------------|---------------|
| Lowest Rating | | | | | | |
| Category | Evaluation Criteria | Gemini™ Analyzer | TruDefender™ FTXi | HazMatID™ Elite | 4500 Series Portable FTIR | HazMatID™ 360 |
| Usability | Sample Preparation/ Data Acquisition | | | | | |
| | User Interface | | | | | |
| | Results Interpretation | | | | | |
| | Display Characteristics | | | | | |
| | Data Transfer | | | | | |
| Deployability | Ease of Setup | | | | | |
| | Decontamination | | | | | |
| | Power Options | | | | | |
| | Portability | | | | | |
| Capability | Durability | | | | | |
| Maintainability | Ease of Maintenance | | | | | |

Table 4-3. Key Specifications

| Key Specification | Gemini™ Analyzer | TruDefender™ FTXi | HazMatID™ Elite | 4500 Series Portable FTIR | HazMatID™ 360 |
|--|---|---|---|--------------------------------------|---|
| MSRP | \$95,000 ¹ | \$53,000 | \$50,000 ² | Not provided | \$55,000 |
| Weight (lb) | 4.2 | 3.12 | 5.05 | 15 | 23 |
| Size (in.) | 10.1 × 5.7 × 2.4 | 8.9 × 4.5 × 2.1 | 10.6 × 5.6 × 3.1 | 8.5 × 11.5 × 7.5 | 17.5 × 12 × 7.5 |
| Operating Temp. (°F) | -4 to 122 | -4 to 104 | -4 to 122 | 32 to 122 | 19 to 122 |
| Ingress Protection (IP) Rating | IP67 | IP67 | IP67 | Not yet rated | IP67 with lid to case closed |
| Shock Resistance | 1.2 m drop test | 1.2 m drop test | 1.2 m drop test | Not yet rated | “Bench handling shock” tested |
| AC Power | ✓ | ✓ | ✓ | ✓ | ✓ |
| Battery Type(s) | Internal lithium ion rechargeable or CR123A disposable | Lithium ion rechargeable or CR123A disposable | Lithium ion rechargeable or CR123A disposable | Lithium ion rechargeable | Lithium ion rechargeable |
| Hot Swap | ✓ ³ | ✓ ³ | ✓ ⁴ | ✓ ⁴ | ✓ ⁴ |
| Charge Time (hr) | 4 | 3 | 4 | 4 | 3 |
| Battery Runtime (hr) | 6 | 4 | 4 | 4 | 2 |
| Selectable User Interface | Based on novice user mode; Expanded functions when used with PC | Based on novice user mode; Expanded functions when used with PC | Based on novice user mode; Expanded functions when used with PC | Separate novice user mode option | Separate novice user mode option |
| Data Formats | .SPC, .RBK (reachback), .TXT, .PDF | .SPC, .ARB, .TXT, .JPEG | Proprietary format, .SPC, .RTF | Proprietary format, .SPC, .PDF, .CSV | Proprietary format, .SPC, .RTF |
| Decontamination Options | Submersible, wipe down, or dry decon | Submersible, wipe down, or dry decon | Submersible, wipe down, or dry decon | Wipe down or dry decon | Wipe down or dry decon; Submersible when lid to case closed |
| <p>Notes:</p> <p>MSRP — manufacturer’s suggested retail price</p> <p>✓ — product is equipped with corresponding feature</p> <p>¹ Includes both FTIR and Raman spectroscopy</p> <p>² Dual diamond model</p> <p>³ Instrument does not need to be shut down or plugged into AC power to change battery</p> <p>⁴ Instrument does not need to be shut down to change battery if plugged into AC power</p> | | | | | |

4.1 Thermo Scientific™ Gemini™ Analyzer

The Gemini Analyzer (Figure 4-1) received an overall assessment score of 4.0 and costs \$95,000 as assessed. This includes a 1 year warranty, 1 year of reachback support, and onsite training for up to 12 students.

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

4.1.1 Usability

The Gemini Analyzer received a Usability score of 4.0. The following information is based on evaluator comments:

- Touch screen easy to use in PPE.
- The option to have touch screen and/or buttons is a significant benefit.
- Very clear and easy to read screen.
- Display even better in the dark.
- Very fast analysis.
- Appreciate zoom-in feature for spectra.
- .pdf data format option is a plus.
- Does not have a novice user-configurable interface, but it is already based on a novice user interface.
- No ability to limit access for different user types.
- Not always clear what icons represent.
- Had to adjust the angle of the screen to be able to read in direct bright light.
- Screen could be larger, and the font point size is small.
- Unfortunately, spectral subtraction option only available on a laptop and you cannot view the residual spectra.
- Would much rather be able to use a thumb drive than an SD card.
- Without cellular service, obtaining reachback support would be time consuming as the user would have to export the data to a storage device, transfer to a computer, then e-mail.
- Does not have wireless connection capabilities.



Figure 4-1. Thermo Scientific Gemini Analyzer

Image courtesy of Thermo Scientific

4.1.2 Deployability

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

- Internal battery allows true hot-swapping of other batteries. If battery management is performed correctly, the instrument could run indefinitely.
- Rechargeable or disposable battery options.
- Long run time (6 hr).
- Submersible decontamination is a plus.
- Would like a strap or lanyard.
- Not sure where to hold it while carrying it, fingers hit display while walking, with large gloves on there is not good contact/grip so there is slip potential.
- May need to transport in case if do not want to carry separate liquid well on your person.
- Not sure how durable mechanized arm will be with routine use.

4.1.3 Capability

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

- Very durable, well designed.
- Bonus that there are no parts sticking out that could snag or break off.
- The charging port and data port covers require significant attention to ensure positive closure and sealing.
- Difficult to seal while wearing gloves.
- Would like a bayonet clip type of connection (like the battery has) for the USB, power, and SD card, which have seals that need improvement.

4.1.4 Maintainability

The Gemini Analyzer received a Maintainability score of 4.0. The following information is based on evaluator comments:

- The second battery well is a positive feature for extended operations.
- Easy to plug in.
- Easy to clean.
- There are some crevices around the screen and the indent around the ATR diamond that might be difficult to clean.

4.2 Thermo Scientific™ TruDefender™ FTXi

The TruDefender FTXi (Figure 4-2) received an overall assessment score of 4.0 and costs \$53,000 as assessed. This includes a 1 year warranty, 1 year of reachback support, and onsite training for up to 12 students.

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

4.2.1 Usability

The TruDefender FTXi received a Usability score of 3.9. The following information is based on evaluator comments:

- Small number of buttons and controls minimize confusion.
- Buttons easy to manipulate and large enough for use while wearing PPE.
- Size of the instrument and buttons very ergonomic and easily reached.
- Good visual cues with user-friendly prompts.
- Green and red color coding helpful for novice users.
- Easy to read, like the enter button.
- Good display and easy to read in the dark.
- Really like that the arm swings out of the way making it easy to load a sample.
- Minimal number of steps to acquire a spectrum. Very simple. Very intuitive.
- Very fast spectral interpretation time.
- .jpg report option added plus.
- Has ability to provide additional information from the ERG and NIOSH pocket guides, including first aid information and suggested PPE.
- Does not have a novice user-configurable interface, but it is already based on a novice user interface.
- Do not like the sample shortcut button.
- Button interface only, no touch screen.
- Would have liked a brighter screen, but large font point size is a plus.
- Some display washout in direct bright light, but adjusting screen angle eliminates glare.
- Direct bright light causes some colors to shift.



Figure 4-2. Thermo Scientific TruDefender FTXi

Image courtesy of Thermo Scientific

- Not all of the buttons are illuminated, which creates difficulties in the dark when trying to view the spectrum.
- Anvil hammer requires the user to turn the top knob to lower the anvil to the crystal. The handle of the anvil is designed in a way that while the user is turning the anvil, the head has to be turned/cocked to watch the anvil lower. This is difficult to do in Level A PPE.
- If using the liquid well, it would be good if it magnetically stuck to the sample area.
- No way to view the spectrum while the scan is occurring.
- Can do spectral overlay, but cannot perform spectral subtraction unless data is moved to a laptop computer.
- May take additional training to effectively use advanced features.
- Could be an issue having only one cellular provider.
- No wireless or Bluetooth options.
- Reachback could be time consuming if cell service is not available.
- Would prefer a USB port instead of a mini SD card, which could be dropped or lost and is hard to remove even without gloves.
- No .pdf file format.

4.2.2 Deployability

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

- Extremely lightweight, narrow enough to carry with one hand, and nothing gets in the way.
- Quick startup with good visual prompts.
- Ability to use disposable batteries a plus.
- True battery hot swap a plus.
- Doors all seal positively.
- Fully submersible is a plus.
- Very light and a good size, but would like a strap or lanyard.
- Too small to hold with two hands.
- May need to transport in case if responder does not want to carry separate liquid.

4.2.3 Capability

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

- Very rugged and well built.

- Buttons are molded with the instrument with a continuous face of rubber, and every button is fully sealed.
- Well protected; all ports and battery located in one location.
- Potentially concerned about a direct hard impact on the anvil.
- Rubber outer case has the potential for wear and tear.
- Battery compartment could possibly be inadvertently opened; better battery compartment latch is needed.
- Needs to be kept still during analysis.
- Limited upper temperature operating range specification (104°F).

4.2.4 Maintainability

The TruDefender FTXi received a Maintainability score of 4.0. The following information is based on evaluator comments:

- Batteries can be hot swapped and they can be charged in the unit or in an external charger.
- Great that arm moves out of the way for easy cleaning.
- Battery case attachment o-ring looks fragile and could be more rugged.
- Indent surrounding the ATR diamond difficult to clean.
- Knob cover and rubber case all need to be removed to clean. Case is difficult to remove.

4.3 Smiths Detection HazMatID™ Elite

The HazMatID Elite (Figure 4-3) received an overall assessment score of 4.0 and costs \$50,000 as assessed. This includes a 1 year warranty, 1 year of reachback support, and onsite training within the continental United States for up to 16 students.

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

4.3.1 Usability

The HazMatID Elite received a Usability score of 3.9. The following information is based on evaluator comments:

- Fast startup.
- Everything about the instrument is straightforward.
- Large buttons, easy to use with Level A PPE gloves.
- Easy to use as only buttons that create an option light up, further simplifying controls.
- Clear screen with good resolution and easy to read in direct bright light or the dark from any angle.
- Simple to obtain spectrum with minimal steps required.
- With only a couple steps for data acquisition, instrument is foolproof.
- Easy results interpretation interface for basic user.
- Ability to transfer data via radio frequency or use a thumb drive is a plus.
- Data transfer is very simple, requiring only a few button pushes.
- Does not have a novice user-configurable interface, but it is already based on a novice user interface.
- Backlight on buttons is not visible in direct bright light and intuitive operation was diminished.
- Screen size is a little small, but font point size is large enough to easily read. Very small printed words on part of the screen.
- There is a built-in liquid well, but it needs improvement to better confine the liquid directly over the top of the crystal.
- Nice to be able to see spectrum overlay, but only does background subtraction and mixture analysis.



Figure 4-3. Smiths Detection HazMatID Elite

Image courtesy of Smiths Detection

- To take full advantage of features like spectral manipulation and advanced analysis, a laptop computer is required.
- Does not provide a “fit quality,” and requires the user to visually inspect the spectra.
- Limited types of data formats. .jpg or .pdf formats would be welcome addition.
- The manufacturer’s data format requires proprietary programs to read.
- A report is not generated with an analysis

4.3.2 Deployability

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

- Startup procedures are very easy and very fast. Only 30 s for startup.
- Lightweight and small.
- Slip resistant sides are nice; easy to grip.
- Easy to hold with one hand.
- Ability to use disposable batteries a plus.
- Fully submersible.
- There is a clear lack of a handle/carrying aid. Would like a strap or lanyard.

4.3.3 Capability

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

- The buttons and fasteners seem very durable.
- Anvil feels like it has the potential to break if it is struck or dropped because of the material it is made from appears to be some type of plastic.

4.3.4 Maintainability

The HazMatID Elite received a Maintainability score of 4.0. The following information is based on evaluator comments:

- Changing batteries is very simple, and battery life indicator is nice.
- Batteries can be charged in the detector or in the charging station.
- Buttons/face easily cleaned.
- Crevices around buttons, backside of detector, and around ports that open could be difficult to clean.
- The charging port hole could be difficult to clean.

4.4 Agilent Technologies 4500 Series Portable FTIR

The Agilent Technologies 4500 Series Portable FTIR (Figure 4-4) received an overall assessment score of 3.5. Cost was not provided. Warranty, reachback support (spectral interpretation not included), and onsite training are available.

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

4.4.1 Usability

The Agilent Technologies 4500 Series Portable FTIR received a Usability score of 4.0. The following information is based on evaluator comments:

- Multiple configurable user modes.
- Very large screen with good user interface.
- Like the way the anvil swings out of the way and sample well is unobstructed.
- Like having capabilities offered to alter the method setup, but a novice user may have difficulty with having access to too many options.
- Like the ability to easily maneuver through screens, but do not like to use a stylus. Would like use of the stylus to be optional.
- Has ability to view spectral residuals.
- Able to observe spectrum during data-acquisition process helpful.
- Built-in cellular and wireless capability and various data formats aids data transfer.
- Like .pdf report option.
- Being able to remove screen from instrument helpful for some situations.
- Stylus use is more awkward when wearing Level A PPE, but not impossible. Once the right touch is learned, it is fairly intuitive.
- The stylus is easy to use, but the software buttons/options on the screen are not laid out conveniently.
- Illumination of power button cannot be seen under direct bright light.
- Touch screen does not work when wearing most gloves.
- Sometimes cannot tell when you do not hit the button completely as there is no indicator (e.g., like an hourglass) to indicate a button has been hit.
- Easy to forget to obtain a background spectrum because no clear software prompt.
- Screen can be removed from the case, but its removal can be somewhat difficult when wearing Level A PPE.



Figure 4-4. Agilent Technologies 4500 Series Portable FTIR

Image courtesy of Agilent Technologies

- Screen has good visibility, but the contrast is reduced in direct bright light. Need to adjust angle to minimize glare if screen is not left in the case.
- The small release on the press can be difficult to operate when wearing Level A gloves.
- Would like to have a concave well for liquid samples.
- Spectra can only be stacked, not overlaid on the tablet computer. However, data can be overlaid on a separate laptop computer.

4.4.2 Deployability

The Agilent Technologies 4500 Series Portable FTIR received a Deployability score of 3.0. The following information is based on evaluator comments:

- Easy to carry, but heavy.
- The carrying handle is somewhat small when wearing Level A gloves.
- The kickstand on the lid of case interferes with the carry handle.
- Not a true hot swap battery.
- Not submersible for decontamination, wipe-down/dry decontamination only.
- Has not been tested yet for IP rating.

4.4.3 Capability

The Agilent Technologies 4500 Series Portable FTIR received a Capability score of 2.3. The following information is based on evaluator comments:

- Heavy-duty anvil with well-made swivel.
- Latches and plastic handle feel sturdy, but possible snagging could occur.
- There is the potential to damage the tablet computer if the lid is closed when the anvil is in the up position.
- The plastic ports on the side of the instrument could be subject to damage.
- Overall, instrument is well-sealed, but the touch pad is less durable.
- Protruding ports and power switch could cause issues by accidentally hitting them or powering off.
- Not rated for shock or water resistance.

4.4.4 Maintainability

The Agilent Technologies 4500 Series Portable FTIR received a Maintainability score of 3.6. The following information is based on evaluator comments:

- Cleaning instructions in quick-start guide are very helpful and clear.
- Button covers and crevices are difficult to clean.

4.5 Smiths Detection HazMatID™ 360

The HazMatID 360 (Figure 4-5) received an overall assessment score of 3.4 and costs \$55,000 as assessed. This includes a 1 year warranty, 1 year of reachback support, and onsite training within the continental United States for up to 16 students.

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

4.5.1 Usability

The HazMatID 360 received a Usability score of 3.4. The following information is based on evaluator comments:

- Buttons and sampling compartment are easy to use.
- Spectral overlay function is good to have.
- Hard to see screen in direct bright light.
- In dark conditions, need flashlight to see sample area.
- Some buttons not usable when wearing Level A gloves so have to use stylus, which is more cumbersome.
- Some of the icons are too small and you can accidentally click on the wrong icon with the stylus.
- Low-resolution screen is very reflective, and can be difficult to see when wearing Level A PPE.
- Does not have a built-in liquid sampling well.
- Performing more advanced data analysis could be confusing to a novice user.
- Finding sample spectra can be difficult.
- Limited data formats.
- Would like to have .pdf option.
- Too many steps required to transfer data and not real intuitive.

4.5.2 Deployability

The HazMatID 360 received a Deployability score of 3.2. The following information is based on evaluator comments:

- Heavy, but carrying handle is large enough to accommodate Level A gloves.
- Handle is narrow, which causes the hand to fatigue.



Figure 4-5. Smiths Detection HazMatID 360

Image courtesy of Smiths Detection

- Low run time.
- Lack of true hot swap battery.
- Startup time is slow.
- Slow to initially warm up the instrument.
- Although it is submersible when the case lid is closed, contamination is more likely to be present near sampling location, which can only be decontaminated by wiping.

4.5.3 Capability

The HazMatID 360 received a Capability score of 3.6. The following information is based on evaluator comments:

- No buttons, just a touchscreen helps with ruggedness.
- Durable unit, but on/off switch could be damaged by too aggressive use.
- Only shock resistant to bench handling shock.
- Minor shock or lots of movement often requires a realignment software step to be performed.

4.5.4 Maintainability

The HazMatID 360 received a Maintainability score of 3.1. The following information is based on evaluator comments:



- Secondary battery charging station is helpful.
- Requires a screwdriver to change battery.
- Difficult to clean crevices.

5. SUMMARY

The usability of all of the portable FTIRs was the most important criterion assessed. The ease of use and quality of both the interface (buttons, screen) and software highly influenced overall usability. The design of the anvil also was important as it influenced the ease of loading a sample and the ability to easily clean the sampling platform. Ease of setup and decontamination were also important factors that were considered, with a submersible decontamination option being highly desirable. Three of the FTIRs had equivalent overall criteria ratings (4.0), having only minor differences in power options or ease of setup. The advantages and disadvantages for the assessed products are highlighted in Table 5-1.

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

Table 5-1. Product Advantages and Disadvantages

| Vendor/Product | | Advantages | Disadvantages |
|---|--|---|---|
|  <p>MSRP: \$95,000</p> | <p>Thermo Scientific™ Gemini™ Analyzer (includes both FTIR and Raman spectroscopy)</p> <p>Overall Score: 4.0</p> | <ul style="list-style-type: none"> • Very durable, well-designed • Touch screen and/or button interface • Very fast analysis • Lightweight (4 lbs) • Long run time (6 hrs) • Submersible (IP67) • 1.2 meter drop tested • True hot-swap batteries | <ul style="list-style-type: none"> • No clear place to hold while carrying; fingers accidentally hit display • Separate laptop required for advanced spectral analysis • Cellular connection capabilities only |
|  <p>MSRP: \$53,000</p> | <p>Thermo Scientific™ TruDefender™ FTXi</p> <p>Overall Score: 4.0</p> | <ul style="list-style-type: none"> • Very rugged and well-built • Very fast analysis • Lightweight (3 lbs) • Submersible (IP67) • 1.2 meter drop tested • True hot-swap batteries | <ul style="list-style-type: none"> • Lowering anvil manually not ideal • Short run time (2 hours) • Low upper operating temperature range (104 °F) • Separate laptop required for advanced spectral analysis • Cellular connection capabilities only |
|  <p>MSRP: \$55,000</p> | <p>Smiths Detection HazMatID™ Elite</p> <p>Overall Score: 4.0</p> | <ul style="list-style-type: none"> • Appears very durable • Rapid/easy startup and data acquisition • Easy to grip • RF data transfer option • Lightweight (5 lbs) • Submersible (IP67) • 1.2 meter drop tested | <ul style="list-style-type: none"> • Does not provide a “fit quality” • Limited data output formats • Screen size is a little small • Separate laptop required for advanced spectral analysis |
|  <p>MSRP: Not provided</p> | <p>Agilent Technologies 4500 Series Portable FTIR</p> <p>Overall Score: 3.5</p> | <ul style="list-style-type: none"> • Heavy duty anvil • User interface very easy to use and follow • Very large screen • Allows spectral residuals to be viewed • Both cellular and wireless capability • Multiple data formats | <ul style="list-style-type: none"> • Stylus must be used if wearing gloves • Carrying handle is somewhat small when wearing gloves • Not rated for shock or water resistance • Spectra can only be stacked, not overlaid unless using a separate laptop |
|  <p>MSRP: \$55,000</p> | <p>Smiths Detection HazMatID™ 360</p> <p>Overall Score: 3.4</p> | <ul style="list-style-type: none"> • Durable • No buttons, just touchscreen helps with ruggedness • Buttons easy to use • Easy to use anvil • Carrying handle good size • Spectral overlay function helpful | <ul style="list-style-type: none"> • Some buttons not usable with gloves, so must use stylus • Screen is low resolution and reflective • Startup time is slow • Limited data output formats • Difficult to clean crevices |

APPENDIX A. AGILENT TECHNOLOGIES 4300 HANDHELD FTIR

It is important to note that the Agilent Technologies 4300 Handheld FTIR is not designed for use in hazardous environments (e.g., hot zones) or while wearing personal protective equipment and it is not marketed to emergency responders. Assessment results for the Agilent Technologies 4300 Handheld FTIR have been separated from the other products and are provided here.

A.1 Assessment Results

Table A-1 presents vendor-provided key specifications for the 4300 Handheld FTIR.

Table A-1. Key Specifications (4300 Handheld FTIR)

| Key Specification | 4300 Handheld FTIR |
|--|--------------------------------------|
| MSRP | \$55,000 |
| Weight | 5 lbs |
| Size | 4 in x 7.5 in x 13.6 in |
| Operating Temp. | 32 °F to 104 °F |
| Ingress Protection (IP) Rating | IP54 |
| Shock Resistance | 1.2 meter drop tested (in case) |
| AC Power | ✓ |
| Battery Type(s) | Lithium ion rechargeable |
| Hot Swap | ✓ ¹ |
| Charge Time | 2 hrs |
| Battery Runtime | 3 hrs |
| Selectable User Interface | Novice user mode option |
| Data Formats | Proprietary format, .SPC, .PDF, .CSV |
| Decontamination Options | Wipe down or dry decon |
| Notes: MSRP — manufacturer's suggested retail price ✓ — product is equipped with corresponding feature ¹ Instrument does not need to be shut down or plugged into AC power to change battery | |

The 4300 Handheld FTIR (Figure A-1) costs \$55,000 as assessed. This includes a 1 year warranty, 1 year of reachback support (spectral interpretation not included), and on-site training.

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

Usability

The following information is based on evaluator comments:

- Good resolution and easy to read display.
- Display does well in direct bright light.
- Screen is small, but effective.
- Trigger pull is a plus.
- Software is fairly intuitive.
- Spectral quality is good.
- Variety of data file formats available.
- Stylus must be used when wearing gloves.
- Stylus difficult to use when wearing Level A gloves.
- Reading screen while applying and visualizing sample contact difficult.
- The instrument is not really designed for measuring small amounts of liquid or powder samples.
- Advanced spectral processing requires a laptop computer.
- Requires a laptop to transfer data from USB port, no other data transfer options.



Figure A-1. Agilent Technologies 4300 Handheld FTIR

Image courtesy of Agilent Technologies

Deployability

The following information is based on evaluator comments:

- Lightweight lanyard was helpful and ergonomic to carry.
- Easy to carry, good handle design, relatively lightweight, and carries like a tool.
- True battery hot swap is a plus.
- Very easy menu-driven setup.
- Straightforward decon instructions in quick-start guide.
- Needs a place for the stylus to reside.
- Lanyard is somewhat thin.
- Slow startup time.

Capability

The following information is based on evaluator comments:

- Buttons are fairly durable.
- Ruggedness OK.

Maintainability

The following information is based on evaluator comments:


- Batteries accessible and easily removed, replaced, and recharged.

A.2 Summary

The Agilent Technologies 4300 Handheld FTIR is not designed for use in hazardous environments (e.g., hot zone) or while wearing personal protective equipment and it is not marketed to emergency responders. Because of this, it is not designed to be decontaminated by dunking, nor was it specifically designed for rigorous decontamination of any residual hazardous materials that may become deposited on it by use in hazardous zones.

The Usability of portable FTIRs was of the highest importance. The ease of use and quality of both the interface (buttons, screen) and software highly influenced overall usability. Ease of setup was also an important factor that was assessed. The advantages and disadvantages for the Agilent 4300 Handheld FTIR are summarized in Table A-2.

Table A-2. Product Advantages and Disadvantages (4300 Handheld FTIR)

| Vendor/Product | Advantages | Disadvantages |
|--|--|--|
|  <p>Agilent Technologies 4300 Handheld FTIR</p> <p>MSRP: \$55,000</p> | <ul style="list-style-type: none"> • Good resolution and easy to read display • Trigger pull is a plus • Good spectral quality • Lightweight and ergonomic • Lanyard helpful • Batteries easily removed, replaced and recharged • True hot swap batteries | <ul style="list-style-type: none"> • Not really designed for measuring small amounts of sample • Advanced spectral processing requires laptop • Requires a laptop to transfer data – no other data transfer options • Stylus difficult to use in PPE |

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

APPENDIX B. EVALUATION CRITERIA DEFINITIONS

The focus group identified 11 evaluation criteria, which are defined as follows.

USABILITY

Sample Preparation/Data Acquisition refers to the ease of preparing a sample for analysis and the number of steps required to acquire a spectrum/result. Focus group participants noted the characteristics of the sample compartment may affect Sample Preparation/Data Acquisition.

User Interface refers to the size and layout of buttons and controls on the detector, as well as the readability of labels on the buttons/controls. User Interface also includes how intuitive it is to navigate the buttons/controls, and how easy they are to manipulate while wearing personal protective equipment (PPE). Focus groups participants noted a configurable user interface based on user experience is preferred (e.g., ability to limit access to certain features for novice users).

Results Interpretation refers to the results of the analysis being easy to understand. The spectral processing options (e.g., spectral subtraction, mixture analysis/residual spectra display) and quality of the spectrum (e.g., signal-to-noise, spectral resolution) may influence Ease of Interpretation.

Display Characteristics refers to the size, contrast, screen resolution, and backlight of the display, as well as the display's readability in direct bright light and low-light conditions while wearing PPE. Display Characteristics may influence the user's ability to see enough detail to perform advanced spectral interpretation.

Data Transfer refers to the ease of transferring the spectrum for reachback (i.e., number of steps and equipment required for transfer to vendor support staff and/or other specialists). Data Transfer includes being able to export the data in common file formats.

DEPLOYABILITY

Ease of Setup refers to the ease of readying the FTIR to take a sample measurement based on vendor-provided instructions in the user manual. Ease of Setup may include the ease of removing the detector from the case, powering up, running a confidence test, cleaning the diamond, and gathering a background spectrum.

Decontamination refers to the steps required to decontaminate the detector as well as the apparent effectiveness of the process (i.e., submersible, wipe down, or dry decontamination only).

Power Options refers to the battery runtime, backup power options (e.g., AC and DC power options), and battery type(s) (e.g., rechargeable or single use, commercially available or proprietary) used by the detector. Power also includes the detector being able to accept alternate battery options (i.e., replace a proprietary battery with a commercially-available battery) and ability to hot-swap batteries.

Portability refers to the ease of carrying the system to the site of intended use. The size and weight of the system, as well as if all components are included in a case and/or feature lanyards or handles, influence Portability.

CAPABILITY

Durability refers to the overall ruggedness of the device, including the sturdiness of its buttons/controls and if it features covered ports and/or a sealed battery compartment. Durability also includes the device's water resistance (i.e., Ingress Protection [IP] rating) and shock resistance.

MAINTAINABILITY

Ease of Maintenance refers to the ease of cleaning the detector, including the sampling accessory, according to vendor recommendations provided in the user manual. Ease of Maintenance also includes the ease of replacing/charging the batteries (e.g., are tools required). Ease of Maintenance does not include decontamination procedures.

APPENDIX C. ASSESSMENT SCORING FORMULAS

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

Category Score Formula

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

Category Score Example¹

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

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

Overall Score Formula

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

Overall Score Example¹

| <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 × 10%) | + (4.5 × 10%) | = 4.1 |

¹Examples are for illustration purposes only. Formulas will vary depending on the number of criteria and categories assessed and the criteria and category weights.