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Body Cavity Screening: Technology Assessment

(Version 1.1)

DOJ Office of Justice Programs
National Institute of Justice

Sensor, Surveillance, and Biometric Technologies (SSBT)
Center of Excellence (CoE)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 EXECUTIVE SUMMARY

The National Institute of Justice (NIJ) Sensor, Surveillance, and Biometric Technologies (SSBT) Center of Excellence (CoE) has conducted a technology assessment of a Body Cavity Screening (BCS) system being developed by Quantum Magnetics (QM, a component of Morpho Detection).[1,2] The research and development (R&D) is funded by NIJ (under Awards 2007-DE-BX-K001 and 2011-IJ-CX-K001) to address the need of criminal justice personnel at correctional facilities to screen persons for metallic and non-metallic contraband concealed in body cavities. The QM system utilizes electric field tomography (EFT) as a new method of detecting concealed contraband on or in a person. This report combines information gathered from a site visit to QM and a survey of criminal justice practitioners to provide an independent assessment of the project and technology to determine commercial maturity, current and projected capabilities, overall value to the criminal justice community, and to assist NIJ in its decision-making and research strategy.

The QM BCS system uses EFT on a human subject to detect the presence of non-metallic objects on or in a person. The system has antenna positioned along the interior perimeter of a large 4' diameter aluminum cylinder for transmitting and receiving low power radio waves. Wire mesh is used as shielding around the lower third of a person and a metal plate is secured as a roof to add additional environmental shielding. The system uses a custom-built multi-channel spectrometer to transmit/receive radio waves. The backend software model subtracts the theoretical signal from a human body, consisting of multiple basic organic materials (e.g., bone, muscle) to reveal the rough presence of foreign objects. The system has only been tested with a large plastic object and has not undergone parametric test and evaluation (T&E) or human subject testing.

QM System Technology Maturity – The current laboratory prototype is at a Technology Readiness Level (TRL) 2-3 (i.e., Technology concept and/or application formulated OR Analytical and experimental critical function and/or characteristics proof of concept).[3]

QM Project Status – The project has suffered from schedule and work efficiency issues due to organizational laboratory moves and the loss of key personnel. Based on information gathered during the site visit, the SSBT CoE estimates that completing the project will require:

- Cost Estimate (includes burdens): $1.2 – 2M (basic research); $0.9 – 1.3M (prototype)
- Schedule Estimate ~2 yrs (basic research); 1 – 2 yrs (prototype)

Criminal Justice Technology Need – Based on the survey results from the limited Technology Working Group (TWG) practitioner group, there continues to be a Medium-High priority criminal justice technology need for Contraband Detection that is able to detect both metallic and non-metallic objects concealed on or in a person in an affordable manner.

SSBT CoE Recommendations – Based on the technology assessment of body cavity screening technologies, the SSBT CoE provides the following three recommendations to NIJ:

1. **NIJ should continue to pursue R&D of body cavity screening technologies capable of detecting non-metallic objects.** Based on the limited TWG survey, the technology need remains at a Medium-High priority. There are few commercial options for meeting this technology need. Therefore, this topic should remain a key priority for future NIJ R&D funding. However, the topic should be left agnostic to the technology approach used to deliver the practitioner capability.

2. **NIJ should investigate regulation and policy issues regarding the use of low dose transmission x-ray technologies in criminal justice contraband screening.** This technology is known to be able to detect non-metallic objects concealed in body cavities. Changes in regulations at the state and federal levels could allow for the technology need to be met by a low-cost technology that is already well established. Studies on the topic from a technical and policy perspective could help educate criminal justice agencies and legislatures.

3. **There does not exist a compelling case to continue funding the current prototype system and QM team.** Although the QM project has made progress in tackling fundamental technical challenges, there remain many technical, programmatic, and operational challenges in the follow-on stages. For this technical topic, NIJ should return to a competitive solicitation to allow alternative performers and technologies.

2.0 INTRODUCTION

The NIJ SSBT CoE has conducted a technology assessment of a Body Cavity Screening (BCS) system being developed by Quantum Magnetics (a component of Morpho Detection). The R&D is funded by NIJ to address the need of criminal justice personnel at correctional facilities to screen persons for metallic and non-metallic contraband concealed in body cavities. The QM system utilizes electric field tomography (EFT) as a new method of detecting concealed contraband on or in a person. This report combines information gathered from a site visit to QM and a survey of criminal justice practitioners to provide an independent assessment of the project and technology to determine commercial maturity, current and projected capabilities, overall value to the criminal justice community, and to assist NIJ in its decision-making and research strategy.

2.1 About the SSBT CoE

The NIJ SSBT CoE is a center within the National Law Enforcement and Corrections Technology Center (NLECTC) System. The Center provides scientific and technical support to NIJ's R&D efforts. The Center also provides technology assistance, information, and support to criminal justice agencies. The Center supports the sensor and surveillance portfolio and biometrics portfolio. The Centers of Excellence are the authoritative resource within the NLECTC System for both practitioners and developers in their technology area(s) of focus. The primary role of the Centers of Excellence is to assist in the transition of law enforcement technology from the laboratory into practice by first adopters.

3.0 QM BODY CAVITY SCREENING PROTOTYPE SUMMARY

The QM BCS system uses EFT on a human subject to detect the presence of non-metallic objects on or in a person. The system has antenna positioned along the interior perimeter of a large 4' diameter aluminum cylinder for transmitting and receiving low power radio waves. Wire mesh is used as shielding around the lower third of a person and a metal plate is secured as a roof to add additional environmental shielding. The system uses a custom-built multi-channel spectrometer to transmit/receive radio waves. The backend software model subtracts the theoretical signal from a human body, consisting of multiple basic organic materials (e.g., bone, muscle) to reveal the rough presence of foreign objects. The system has only been tested with a large plastic object and has not undergone parametric T&E or human subject testing.

Table 1: QM Body Cavity Screening Prototype Summary

Characteristic	Details
Company	Morpho Detection
Model and Name	NIJ Body Cavity Screening System
Technology	Electric Field Tomography
Size Class	Fixed
Dimensions	7' x 5' x 5' (approximate)
Weight	*Unspecified*
Detect Metals	Theoretically yes, but unconfirmed
Detect Non-Metals	Yes – Plastic
Detect Cavity Concealed	Yes
Which Cavities	Unconfirmed, but theoretically all torso/abdomen cavities
Size of Detected Objects	Large cylinder (4" diameter x 12" height), theoretical minimum is "finger" size
Scan Rate	5 minutes
Inspection Time	*Undetermined*
Penetration Depth	*Undetermined*
Spatial Resolution	*Undetermined*
Info View	Cross section plane with amorphous objects
Image Visualization	Color view with background subtracted
Power	5 VAC, Power Unspecified
Regulatory & Compliance Safety	IEEE
Warranty	N/A
MSRP	N/A
Other	Early stage laboratory prototype

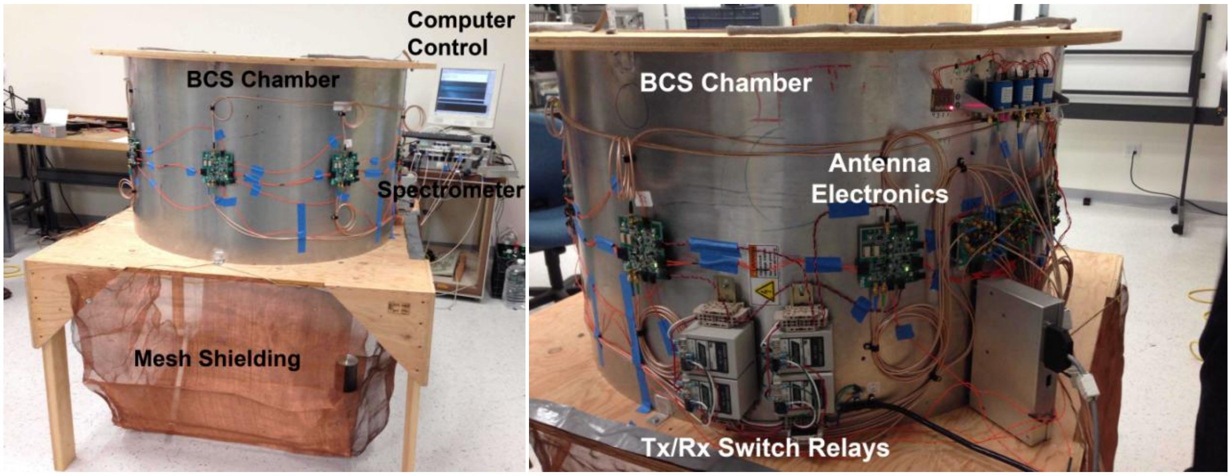


Figure 1: QM BCS System
Photo by NIJ SSBT CoE

4.0 ASSESSMENT QUESTIONS

A set of questions were prepared by the CoE to ascertain the technical, programmatic, and operational details of the QM BCS system. These questions were used as a guide to establish the R&D history, current status, and future plans of the technology and project. SSBT CoE staff conducted a site visit to the QM research facilities (Santa Ana, CA; December 17, 2013), where a detailed discussion was held with QM research staff. These questions were either posed explicitly, or the information gathered from organic conversations about the research project.

4.1 Programmatic

What is the timeline for wrapping up the grant?
QM plans to perform limited human subject research (HSR) in January 2014, with a final report on the project to be delivered to NIJ at the end of January. All project activities are expected to conclude at that time. The period of performance of the grant extends through March, but there will likely be insufficient funding to support work past January.

Describe the human subject testing – process, objectives, data, and subjects
The plan is to focus on collecting images from ~5 people to investigate differences in resulting signals and coefficients. The gathered data from imaging will be used to map out conductivity coefficient variations to explore the validity of the current background subtraction approach/model. No foreign objects will be included in the testing.

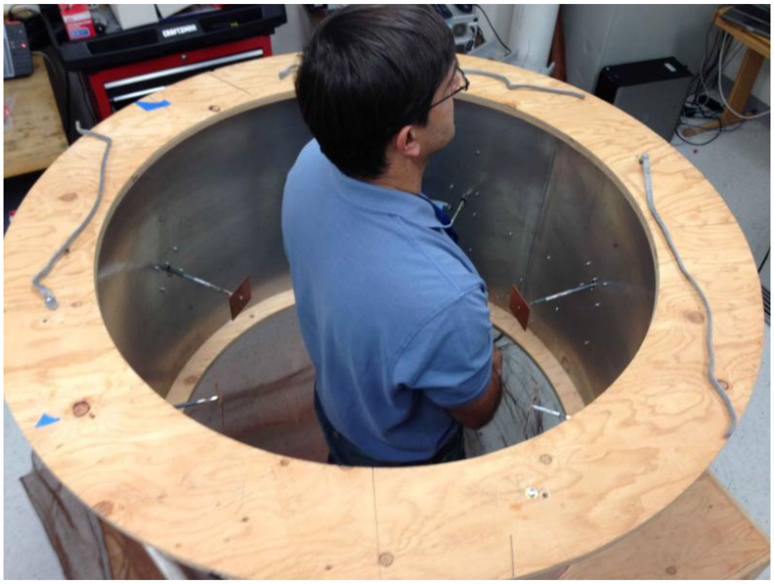


Figure 2: Human Subject Inside BCS Device
A person stands inside the QM BCS system to demonstrate the method of scanning and relative dimensions of the system.

Program narratives describe an internal QM Commercialization Report to determine commercial feasibility. What were the high level conclusions and recommendations of that report? Can a copy be shared with NIJ and/or the CoE?
The QM project staff was unaware of the existence of such a report and had never seen it.

What are the remaining R&D stages that need to be conducted?
The QM team identified several action items and steps that would be needed during follow-on work to complete basic research and move on to prototype development. SSBT CoE has amended the estimate to include testing needed prior to hand-off to NIJ or a third party for operational evaluations.

<u>Obtain a new spectrometer with 8 channels</u> – The current system is hardware limited in its imaging. The spectrometer has 4 channels, which limits the active receivers to three. The scan uses one set and then changes the set of receivers before changing the transmitter. The ideal system would have a separate dedicated channel for each transmitter/receiver. This affects the scan time and the phase resolution. As of December, the scan time was improved to 5 minutes, down from 25 minutes, but that time is primarily due to the time needed to switch relays between Tx/Rx sets and transfer the data; the transmission for a given antenna is only active for ~5 milliseconds. During follow-on work, the QM team would want to have a new custom spectrometer built, or perhaps modify a high-end commercial one.

<u>Redesign the device chamber to be realistic to operations</u> – When the device was designed, the QM machine shop mistakenly took the diameter to mean the radius, so the cylinder scanner region is four times as large as it should be. As a result, the antennas stick out from the inner walls more than designed (they should have just been an inch from the wall). This introduces interference from the rods that hold the square antenna, affecting the gain and phase.

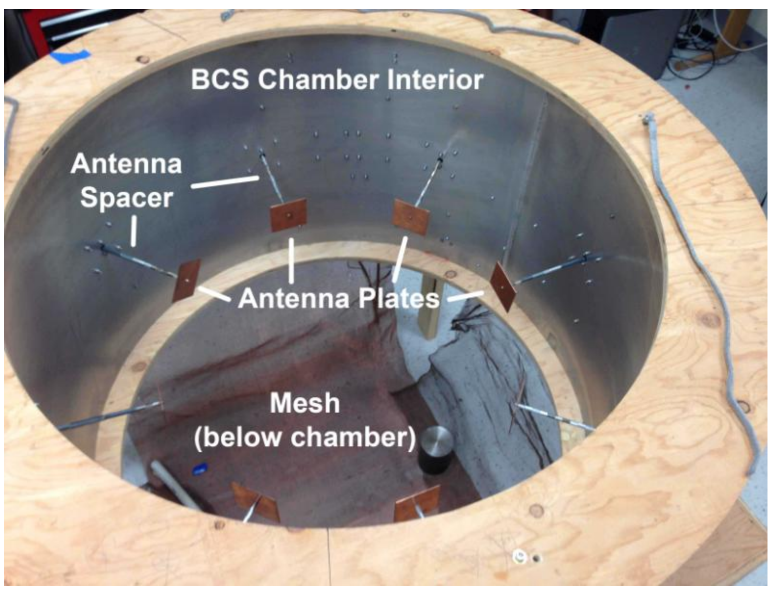


Figure 3: BCS System Interior

In addition, the current laboratory prototype uses a solid cylinder to image targets and subjects. For operational use, the system will need to be redesigned from a physical perspective to accommodate subject processing, ergonomics, and operational workflows. QM staff has tentatively identified several possible configurations – a horseshoe with an open gap, a lowered ring, or a closet. However, all of these designs introduce possible deviations and/or complications to the transmission and receipt of image scans, requiring further R&D and testing.

Finally, proper shielded will need to be incorporated into the final system design to cover the full perimeter of the scanning region. Background noise was found by QM to be problematic, but shielding below, around, and above the subject scanner was sufficient to mitigate the effects. However, the laboratory setup for the shielding is inadequate for an operational prototype and would need to be a conscious component of the final redesign.

<u>Revisit simulations to account for three dimensions and underlying modeling theory</u> – The modeling currently used by the QM scanner uses electric field lines and assumes the phase changes along those lines. The QM lead believes this is oversimplified and that a more accurate model needs to be developed using simulations. Another area of improved modeling would take advantage of a more accurate and complex human body model with respect to dielectric and conductivity properties. A model and its supporting data are available for purchase, called ANSYS.

<u>Collect data on various target scans (material composition and size)</u> – As of December 2013, the QM team had only ever conducted tests using a large plastic cylinder. This is far from the target detection goals, both with respect to target size and material composition. Extensive R&D remains to be performed where laboratory data is collected on these targets and the resulting modeling and detection is investigated.

<u>Conduct human subject research data collection using targets</u> – No imaging has been performed with a human subject concealing an object on their person. Extensive data collection, testing, and analysis are needed during the advanced prototype development stage to determine the operational limitations, feasibility, and performance of the system.

How long for each stage, how much estimated money?

QM provided a rough cost and schedule estimate for the remaining work to develop the system to an advanced prototype suitable for field testing by a third party. The SSBT CoE then revised that estimate based on its observations of the project and RDT&E experience:

- Cost Estimate (includes burdens): $1.2 – 2M (basic research); $0.9 – 1.3M (prototype)
    - New Spectrometer Board: $500k – 1M
    - Modeling: $200k – 300k
    - Imaging R&D: $300k – 400k
    - Electronics R&D: $200k – 300k
    - Physical Construction: $200k – 300k
    - Installing Prototype Electronics: $400k – 600k
    - Internal HSR T&E: $300k – 400k

- Schedule Estimate ~2 yrs (basic research); 1 – 2 yrs (prototype)
    - Addressing basic technical issues (e.g., imaging, modeling): ~2 yrs
    - Building an advanced prototype: 1 – 2 yrs

If NIJ does not continue funding, what are QM's plans for the technology with respect to R&D and commercialization?
Morpho Detection has had some interest in adopting the technology to detect bombs in bodies. However, currently (i.e., December 2013) there are no plans to continue working past the NIJ grant. Morpho may reach out to the Transportation Security Administration to see if they are interested. The QM team was open to pursuing a future open NIJ solicitation relevant to this work, but the team would need the right skill set by bringing on additional personnel.

4.2 Technical

What are the primary technical challenges standing between advanced prototype and commercialization?
Much of the technical challenges are addressed in the remaining stages discussion (see Section 4.1 Programmatic). Overall, QM reports that the primary challenge is imaging resolution; throughput and noise have been found to be manageable. Resolution of the system could be improved by revising the conductivity models to be more accurate, upgrading the spectrometer, and redesigning the system. From the SSBT CoE perspective, it is difficult to fully outline the technical challenges because almost all of the data collection on different target objects with and without human subjects has not yet been performed. Lack of relevant data is the primary limitation and challenge for the project. Until that is addressed through additional R&D is difficult to identify or speculate on the real roadblocks to developing the system.

What Technology Readiness Level (TRL) does QM place it at?
The current laboratory prototype is at TRL 2-3 (i.e., Technology concept and/or application formulated OR Analytical and experimental critical function and/or characteristics proof of concept).[3]

Do they plan to deliver a lab prototype to NIJ at end of the grant? If not, why?
QM does not plan to deliver a laboratory prototype to NIJ at the end of the project. The system is still in a laboratory stage and not fully integrated to allow for third-party use. In addition, no manual has been prepared to instruct users. QM is willing to deliver the system if NIJ requires it; this will include the table, custom spectrometer, and software.

The Year-3 program narrative described issues with the IRE partnership, and planned to explore non-EFT methods of detection (inductive coupling, multiple freq). Did that happen, or focused on EFT?
No alternative methods of detection were explored in the program, only EFT imaging.

Has the System Requirements Definition (SRD) document evolved over the life of the project?
No, the SRD has not been revisited or revised since its creation at the beginning of the project.

Have interactions with other material types been explored? QM only discussed plastic in the reports.
Only plastic targets have been used during R&D and testing.

How does this support or align with detecting plastic objects on someone's person but not in a body cavity?
QM has not considered operational procedures or contraband strategies, nor has any testing been performed using plastic objects on a person.

What size plastic object can be reliably detected in its current design? Any reason to expect this will improve?
QM has not conducted tests to determine the detection limit; only a single large plastic cylinder has been imaged (4" diameter x 12" height).

Does the detection theory support detecting and resolving the size requirements spelled out in the SRD?
Theoretical modeling has been performed based on field line simulations. According to QM, detecting the small plastic target goal requires phase stability of approximately 10 – 100 microradians, which is within the noise of the system. Based on these simulations, a target the size of a finger should be detectable. However, the QM lead had some questions about the accuracy of the modeling approach, and would like to see simulations revisited using alternate frameworks.

Apply all the market survey categories to the current prototype:
See Section 3.0 QM BODY CAVITY SCREENING PROTOTYPE SUMMARY

4.3 Practitioner Engagement

Describe the process of practitioner engagement during planning (2008 and beyond)
During the first year of the project in 2007-2008, QM engaged corrections practitioners to assist in developing performance specifications.[1,4] Specifically, the team sought to answer:

1. What sorts of contraband are to be detected?
2. What is the smallest example of each type to be detected?
3. Should the EFT implementation be found infeasible, is an EIT implementation acceptable (electrode-coupled contacting)?

Three regional corrections product assessment group meetings were attended and the technology and project presented. From those meetings, an SRD document and set of performance goals was established:

1. Detection Goals
    a. Nonferrous metal the size of a .22 caliber bullet
    b. Ferrous metal the size of a single razor blade
    c. Plastic the size of a plastic toothbrush handle (i.e., cylinder 8 mm in diameter by 10 cm long)
2. Scanning does not require contact with the subject’s skin
3. Accommodate subjects up to the 95th percentile in girth
4. Device is stowable when not in use
5. Easy to use and provide intuitively understandable results
6. Cost similar to the $6,000 now paid for metal detection portals
7. Scan times of several tens of seconds per subject

No additional practitioner engagement has been performed since the SRD document was initially established.

Who has the team been collaborating with throughout R&D to double check direction and requirements and get feedback?
No additional practitioner engagement has been performed since the SRD document was initially established.

Corrections CoE involvement? Institutional Corrections TWG feedback?
No additional practitioner engagement.

4.4 Operational Use

How does the prototype function now and how is it intended to be used in an operational setting (details on workflow, information provided, technical limitations)?
The QM has been focused on basic R&D and has not considered the operational use of the system.

How does it fit within the current technology market? How does it align and compliment metal detectors?
The current QM system is being developed to detect concealed plastic contraband. No tests have been performed with metal targets. The developers envision the system to be used in conjunction with traditional metal detectors.

Safety of frequencies at power levels used?
The scanner operates at low voltages and power (± 5V) and at common frequencies rated as being safe for humans (1 – 20 MHz). The system is entirely safe for human use.

What regulations/compliance would this device fall under before being used in the field?
QM is working against IEEE standards related to EFT (specific standards not provided). However, because of the low voltages and frequencies, the system is not subject to any specific regulations.

Is the Concept of Operations to provide a binary flag of suspicious activity to warrant body cavity search or to provide visual mapping to determine what the object is?
The system will provide an alert when an anomaly is detected, but will not provide visual mapping or any spatially resolved object images.

5.0 CRIMINAL JUSTICE TECHNOLOGY NEED

To determine the technology need and operational requirements of a body cavity screening system, nine (9) criminal justice practitioners were surveyed. The Sensors & Surveillance Technology Working Group was solicited, as were the TWGs of the Corrections CoE. The practitioners who volunteered were provided an identical set of questions. The backgrounds of the respondents were as follows:

- Corrections (State/Local) – 3
- Corrections (Federal) – 1
- Law Enforcement (State/Local) – 3
- Forensics – 1
- Courts – 1

In the following subsections, the questions from the surveys are provided verbatim in *italics* followed by the aggregated responses and any necessary explanations or clarifications.

5.1 Sensors & Surveillance Technology Needs: Priorities

<u>Question 1:</u> *Below is the current list of Sensors & Surveillance Tech Needs from 2011. They are included here to put Body Cavity Screening into context among the other technology needs. Please rate them each as High, Medium, or Low priority; if a Tech Need has been adequately addressed in the community and/or marketplace, please rate it for Retirement. If you are unsure as to the state of the technology, assume it is an unfulfilled need and rate accordingly.*

The respondents were asked to rate the technology need priority of all existing technology needs currently captured in the Sensors & Surveillance TWG Technology Needs document. This account of priority needs was last revised during the 2011 Spring TWG Meeting.[5] The individual technology needs were listed in alphabetical order and no indication of the existing priority rate was provided, so as to elicit unbiased assessments. Respondents were also given a choice of completely retiring a technology need, indicating that NIJ should no longer pursue R&D investments in this area.

<u>Table</u> 2 lists the technology needs and the previous and revised priorities based on the responses of the pool of practitioners. An average rating has also been calculated based on a simple scheme of High = 3, Medium = 2, Low = 1, and Retire = 0. <u>Figure 4</u> depicts the technology needs in a bar chart format. Based on the distribution of ratings, an interim threshold was set for High/Medium/Low of 2.49/1.99/1.49 respectively. Although the first inclination might be to use 2.49/1.49/0.49, this does not differentiate the topics sufficiently to be useful to decision makers.

The Contraband Detection technology need is the one that the body cavity screening technology falls under. Based on these survey results, it is tied for the fourth highest technology need and would likely be considered a Medium-High priority. As a side note, the Detection of Hazardous Conditions for First Responders and Body-Worn Cameras possessed the largest deviation between 2011 and these revised priorities.

Table 2: Sensors & Surveillance Technology Needs Priorities

Tech Need	Description	Priority (2011)	Priority (Revised)	Priority Rating
Detection of Hazardous Conditions for First Responders	Determine whether a first responder has arrived at a scene that contains hazardous chemical conditions	Low	High	2.67
Improved Tactical Situational Awareness	Determine the location of suspects or other persons of interest in buildings behind walls	High	High	2.67
Early Warning and Detection of Threats	Identify contraband and unauthorized individuals prior to entering a school or public building	Medium	High	2.56
Cell Phone Management (Law Enforcement)	Acquire and manage access to a specific telephone in a tactical situation.	High	Medium	2.44
Contraband Detection	Detect contraband, both metallic and non-metallic, concealed on or in a person in an affordable manner	High	Medium	2.44
Cell Phone Management (Corrections)	Detect or manage the use of cell phones in correctional institutions	High	Medium	2.33
Improved Video Analytics	Automated, real-time event detection and monitoring from video surveillance	Medium	Medium	2.33
Digital Multi-Media Evidence (DME) Output Technical Recommendations	Extract full streams of DME while maintaining the integrity of metadata; DME interoperability recommendations	High	Medium	2.22
Community Video Technical Recommendations	Recommendations (technical and deployment) for the use of surveillance cameras in commercial businesses to improve their usability in investigations and courts	Medium	Medium	2.11
Surveillance Video Enhancements	Improved compression and storage methods for surveillance video data	Low	Medium	2.11
Interview Room Standards	Standards for the collection, processing, and editing of interview room digital multi-media evidence	High	Medium	2.00
Deception Detection	Detect deceptive or lying behavior from a person encountered in the field or at an interview location	Low	Low	1.89
Detection of Disposed Items During Officer Pursuit	Locate discarded items at the conclusion of foot pursuits in a broad range of environments	Low	Low	1.89
Gun Shot Residue (GSR) Detection	Process clothing or objects for GSR in the field in a reliable, real-time manner	Low	Low	1.89
Trace Blood Detection	Detect trace chemicals and blood at crime scenes quickly and safely	Medium	Low	1.89
Body-Worn Cameras	Technical recommendations for the use of body-worn cameras	High	Low	1.67
Detection of Buried Bodies or Evidence	Effective tools to assist in locating bodies or other evidence hidden underground	Low	Low	1.67
Forensic Photography Training and Guidelines	Improved training and guidelines for nurses capturing photographic forensic evidence	Low	Low	1.56

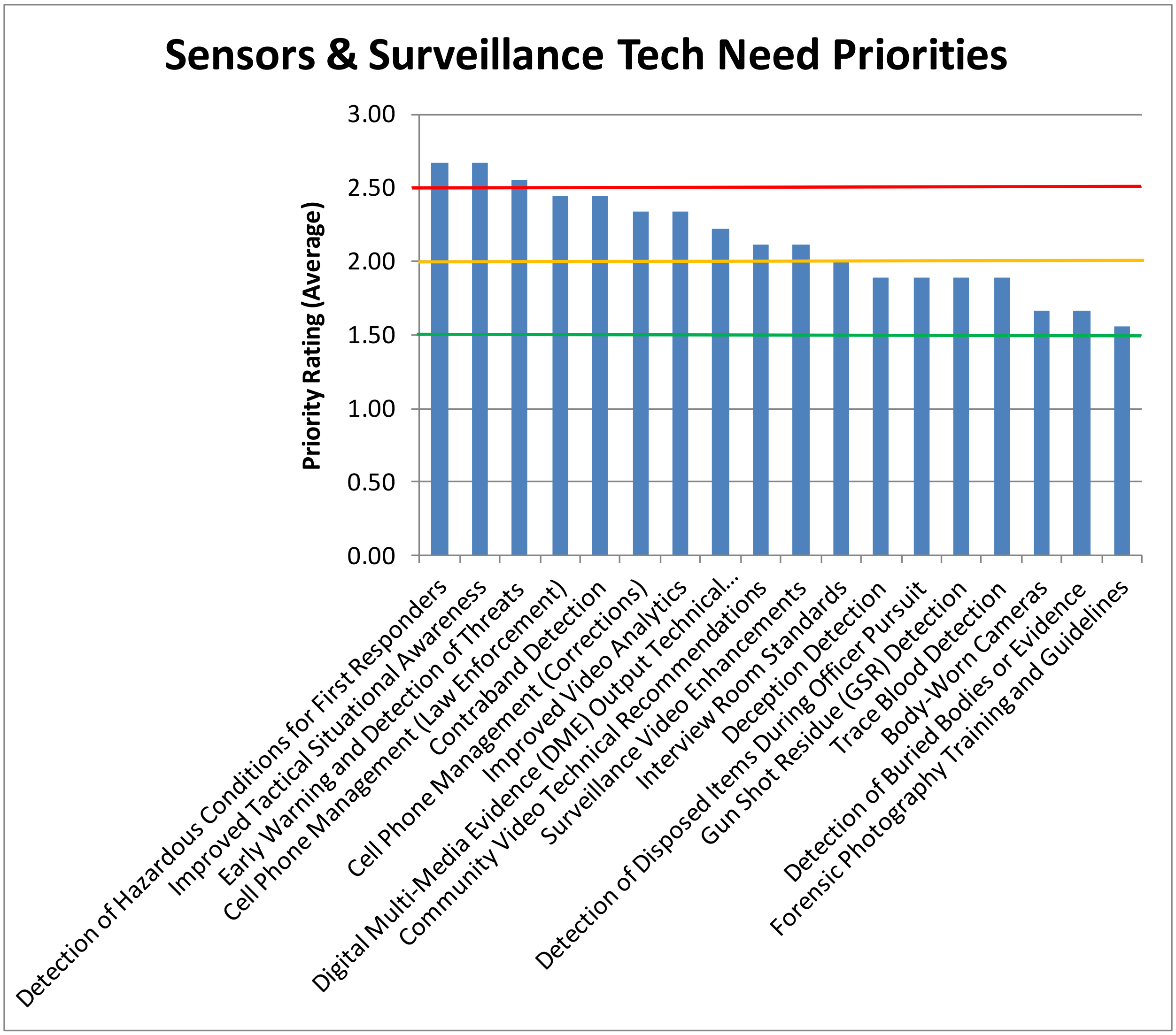


Figure 4: Sensors & Surveillance Technology Needs Priorities

5.2 Body Cavity Screening System Requirements

<u>Question 2:</u> *A working set of operational requirements for Body Cavity Screening technologies is listed below:*

- *Detection Goals:*
  - *Nonferrous metal the size of a .22 caliber bullet*
  - *Ferrous metal the size of a single razor blade*
  - *Plastic the size of a plastic toothbrush handle (i.e., cylinder 1/4 inch diameter by 4 inches long)*
- *Scanning does not require contact with the subject's skin*
- *Accommodate subjects up to the 95th percentile in girth*
- *Device is stowable when not in use*
- *Easy to use and provide intuitively understandable results*
- *Cost similar to the $6,000 now paid for metal detection portals*
- *Scan times of several tens of seconds per subject*

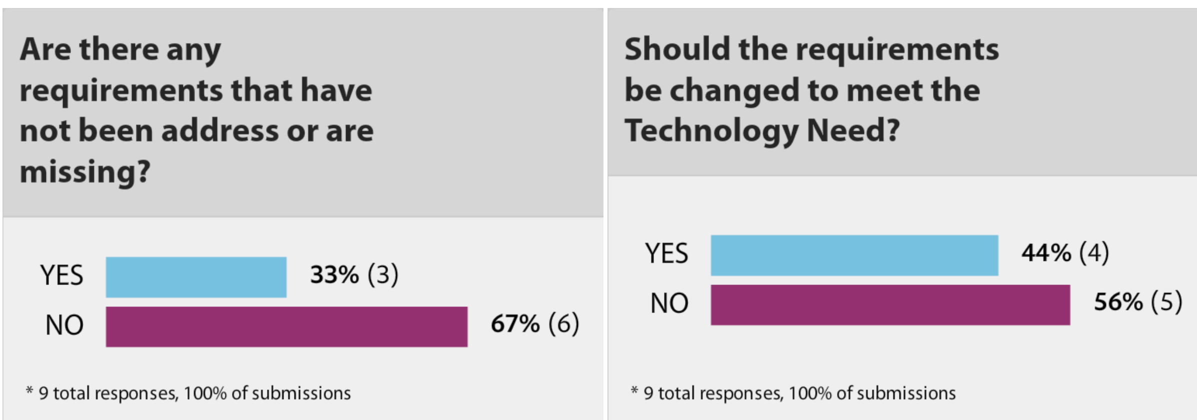


Figure 5: BCS Requirements Survey Results

<u>Question 2b:</u> *If you answered YES to either question, please provide feedback on what should be revised to better reflect operational needs. Note that loosening the requirements is also an important option to better facilitate R&D options.*

Responses (provided unedited):

1. **Respondent #1** – The ability to located smaller ferrous, non-ferrous, plastic, and ceramic items, such as plastic bags containing drugs, Sim cards, plastic chargers, ceramic blades, etc. Low dosage x-ray will safely accomplish this mission and the technology already exists. Many states have existing laws in place, written for the medical diagnostic community years ago, requiring an x-ray technician certification when using any type of x-ray device on humans. This requirement virtually eliminates law enforcement/detention use since it is not practical to send officers to a two year x-ray technician course design for medical applications. If we focus on re-writing the laws to accept low dosage x-ray for security screening (actually less radiation than experienced by a three hour flight at 30,000 feet in a commercial airliner for example) we will have a solution. It works very well and is in use in several states already

2. **Respondent #2** – what about smaller plastic containers e.g. condoms that contain liquids, powders, and/or pills
3. **Respondent #3** – The goals speak to a portable device with the requirement for it to be stowable. While portability can be beneficial, pass through devices similar to metal detectors should not be ruled out or excluded.
4. **Respondent #4** – Must not be harmful to human subjects after repeated exposure (i.e., no x-rays). User interface display must provide appropriate masking of genitalia to accommodate privacy concerns.

5.3 BCS Applications in Criminal Justice

Question 3: *How would a body cavity screening device (that meets the full requirements in Question 2) be used in criminal justice operations? Please list specific applications and/or scenarios.*

Responses (provided unedited):

1. **Respondent #1** – To screen defendants before they come to court and after they leave court. Courts have less security than the jail. Easier to obtain metal and other weapons.
2. **Respondent #2** – Entry into a correctional setting (contracted worker, visitor, corrections officer), Airport, Entry into a secure area near a VIP (close proximity presidential events)
3. **Respondent #3** – Inmate/detainee applications to detect contraband/drugs/weapons. Most common intercept scenarios: book-in/admissions, return from work details, return from court, intelligence follow up, inmate transfer, locating evidence, etc. Additional applications: managing intensive probationers/parolees, screening of informants prior to drug purchases, etc.
4. **Respondent #4** – Screening a subject in the field, student at a school or institution, or screening at a booking/holding facility.
5. **Respondent #5** – search incident to custodial arrest
6. **Respondent #6** – For a correctional institution they could be used to scan offenders, visitors, and staff for contraband as they move in, out, and through a facility. The ability to quickly scan for objects on a person would reduce the number of physical pat searches and possibly the number of unclothed body searches. Both time intensive and potentially dangerous for correctional staff.
7. **Respondent #7** – Intake processing of detainees/inmates in correctional facilities. Investigatory processing of persons suspected of concealing contraband on their person in correctional facilities. Unobtrusive processing/screening of visitors/staff in correctional facilities. May also be useful for TSA airport screening if the throughput time was acceptable.
8. **Respondent #8** – Screen during the booking process, screen entering court house lock-ups, screen when returning from court or medical appointments, screen when returning from visiting/attorney room, screen during cell searches, screen when reasonable cause exists

5.4 Feasibility of BCS Technology Limitations

Based on the known functionality and limitations of the QM BCS system, a set of questions was posed in the survey to determine if proceeding with such a device to an advanced prototype or commercial maturity state was a worthwhile endeavor. If an inherent limitation of the QM system was found to be unacceptable, then it is important to determine that as early as possible so as to either revise R&D activities or reallocate NIJ strategic funding. These questions were born out of discussions with QM staff during the site visit by CoE staff. This section covers Questions 4 – 8 of the survey.

5.4.1 Detection of Metal Objects

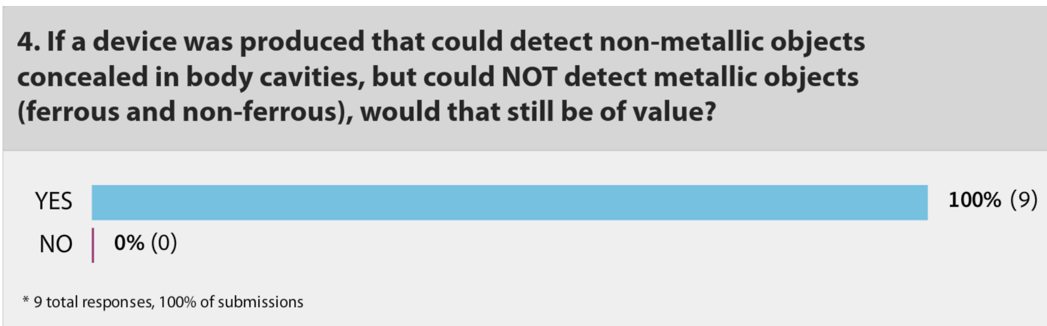


Figure 6: Detection of Metallic Objects: Value

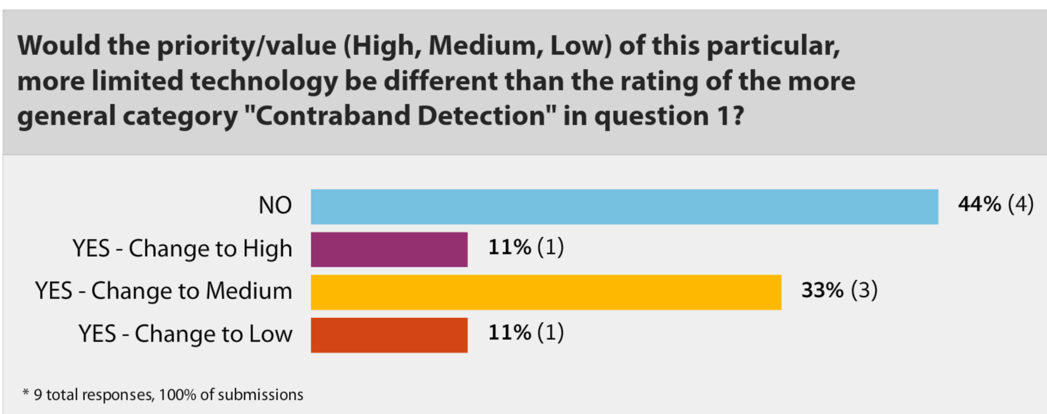


Figure 7: Detection of Metallic Objects: Priority Change

Table 3: Detection of Metallic Objects: Revised Rating

Tech Need	Priority (2011)	Rating (Base)	Avg Rating (Revised)	Avg Priority (Revised)
Contraband Detection	High	2.44	2.22	Medium

5.4.2 Enclosed System for Scanning

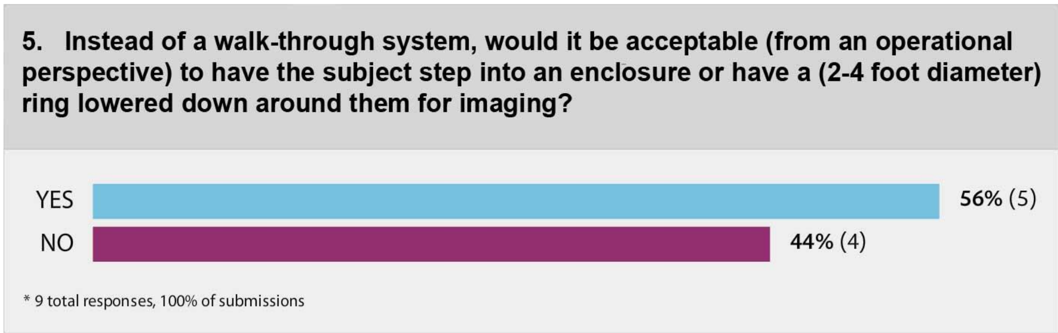


Figure 8: Enclosed System for Scanning: Value

5.4.3 Scan Time

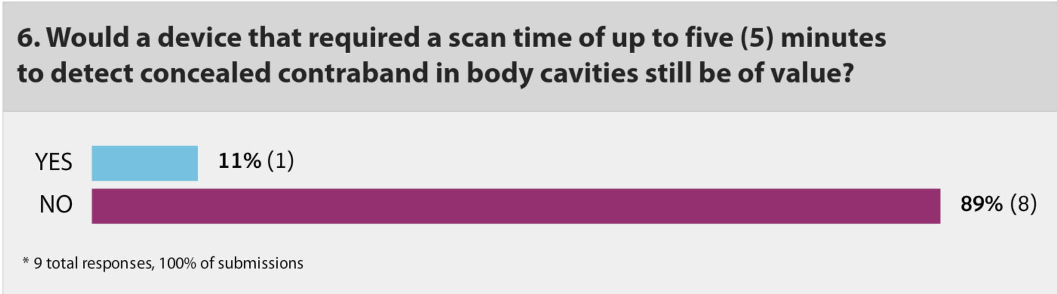


Figure 9: Scan Time: Value

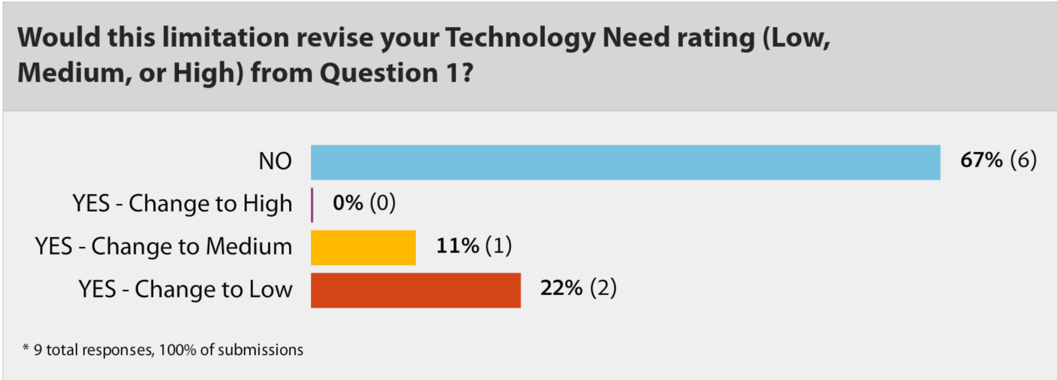


Figure 10: Scan Time: Priority Change

Table 4: Scan Time: Revised Rating

Tech Need	Priority (2011)	Rating (Base)	Avg Rating (Revised)	Avg Priority (Revised)
Contraband Detection	High	2.44	2.00	Medium-Low

5.4.4 Audio-Visual Alert

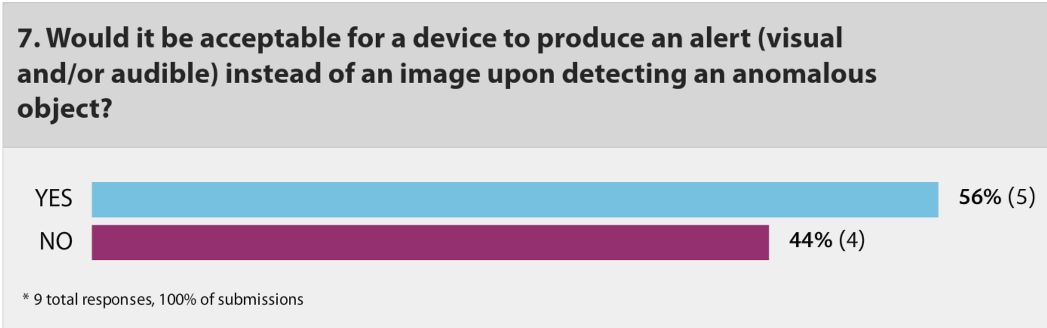


Figure 11: Audio-Visual Alert: Value

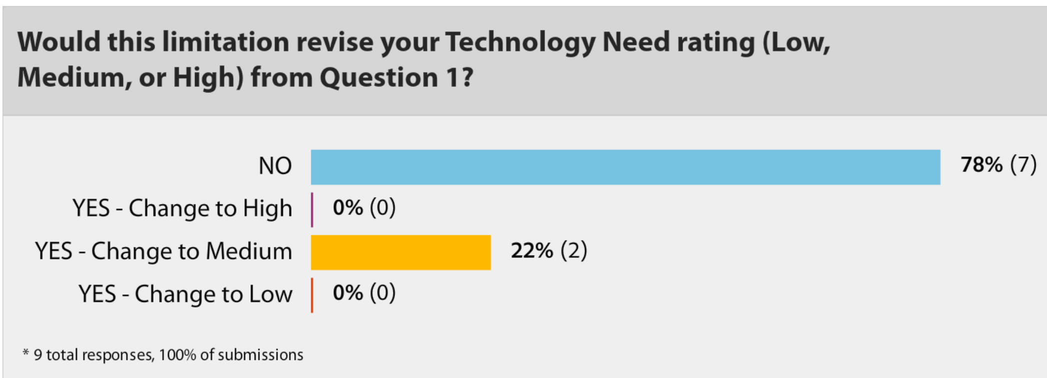


Figure 12: Audio-Visual Alert: Priority Change

Table 5: Audio-Visual Alert: Revised Rating

Tech Need	Priority (2011)	Rating (Base)	Avg Rating (Revised)	Avg Priority (Revised)
Contraband Detection	High	2.44	2.33	Medium

5.4.5 Torso Scanning

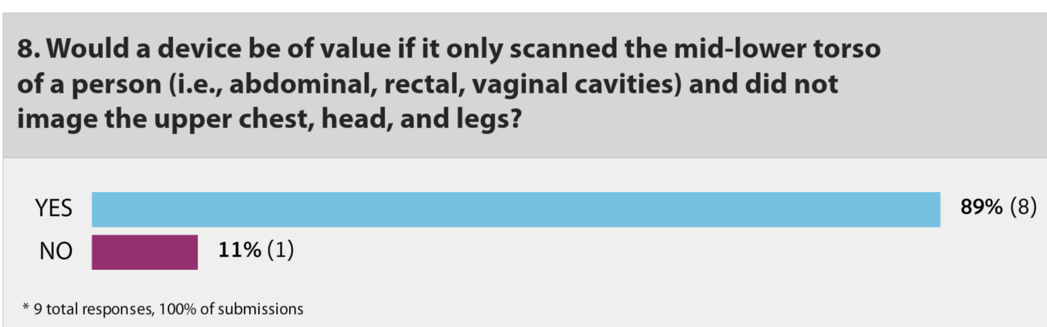


Figure 13: Torso Scanning: Value

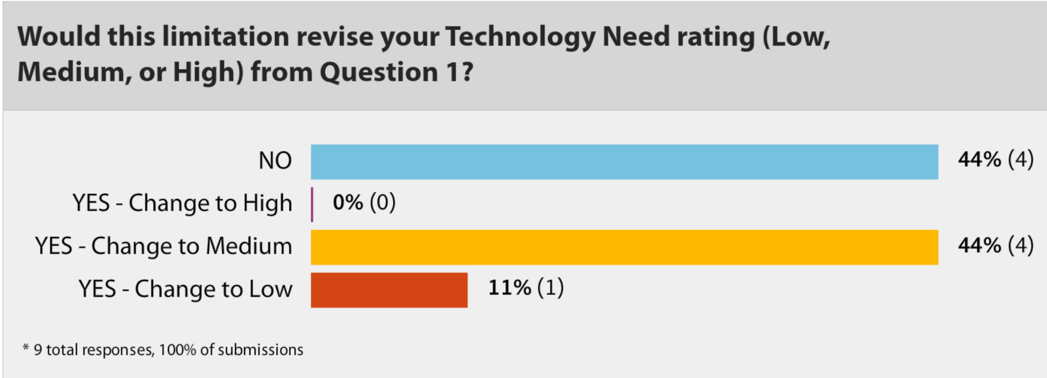


Figure 14: Torso Scanning: Priority Change

Table 6: Torso Scanning: Revised Rating

Tech Need	Priority (2011)	Rating (Base)	Avg Rating (Revised)	Avg Priority (Revised)
Contraband Detection	High	2.44	2.11	Medium-Low

5.5 Image Testing of Other Materials

Question 9: The current requirements (see Question 2) address the detection of plastic, but do not explicitly list various other non-metallic materials as contraband targets to be detected. Note that this does not mean the system is unable to detect these materials; in theory any foreign materials above a certain size threshold should be detected. For the materials below, indicate whether they should be explicitly incorporated into laboratory and field testing to document the system's ability to detect those types of contraband. A NO response means that testing for plastic and metals is sufficient. Note that this will add additional R&D burdens to the developer and third party testing.

Table 7: Image Testing of Other Materials

Material	Positive Response For Inclusion in RDT&E
Explosives	89%
Baggies or packets of powders (e.g., drugs)	78%
Containers of liquid or gels	67%
Ceramic	56%
Bundles or rolls of paper (e.g., currency)	56%
Wood	44%

5.6 Minimum Detection Rates

Question 10: What would constitute an acceptable minimum detection rate for a device attempting to image the following types of contraband concealed in body cavities?

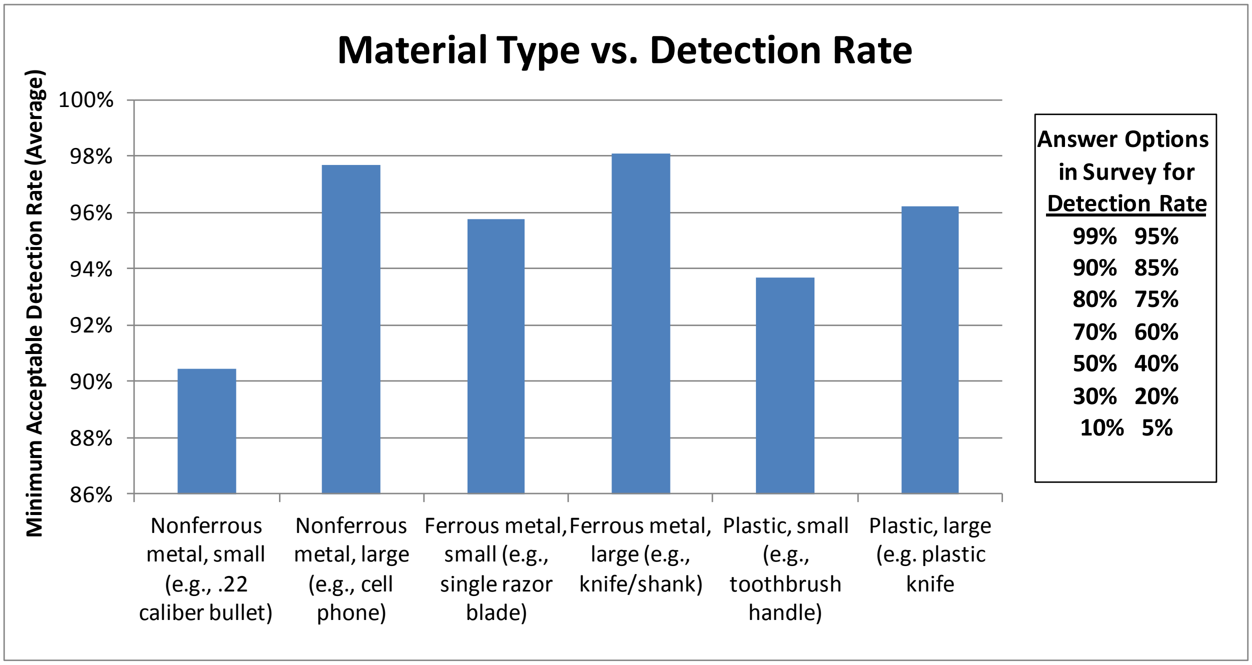


Figure 15: Material Type vs. Minimum Detection Rate
The options offered to the respondents when answering this question are on the right.

6.0 ANALYSIS & DISCUSSION

6.1 QM System Technology Maturity

The current laboratory prototype is at TRL 2-3 (i.e., Technology concept and/or application formulated OR Analytical and experimental critical function and/or characteristics proof of concept). The remaining technical challenges are addressed in detail in Section 4.1 Programmatic and listed here for reference:

1. Obtain a new spectrometer with 8 channels
2. Redesign the device chamber to be realistic to operations
3. Revisit simulations to account for three dimensions and underlying modeling theory
4. Collect data on various target scans (material composition and size)
5. Conduct human subject research data collection using targets

In addition to these technical challenges, there are operational aspects of the technology that QM has mostly ignored. Beyond the initial 2008 requirements gathering efforts to determine an SRD document, there has been no engagement with the criminal justice community during the execution of the R&D program, including decision points where engineering decisions have been made that affect the system's operational us (e.g., scan time, ignoring metallic targets to focus exclusively on non-metallic objects). These engineering choices may have been the right ones, but without practitioner input they could focus the R&D in the wrong direction or place too greater or little an emphasis on a certain operating specification.

From the SSBT CoE perspective, it is difficult to fully outline the technical challenges because almost all of the data collection on different target objects with and without human subjects has not yet been performed. Lack of relevant data is the primary limitation and challenge for the project. Until that is addressed through additional R&D is difficult to identify or speculate on the real roadblocks to developing the system.

The QM project established a set of requirements for the finished advanced prototype at the beginning of the project. Comments below discuss whether this BCS system is on track to meet these requirements.

- **Detection Goals:**
  - **Nonferrous metal the size of a .22 caliber bullet** – **UNKNOWN**; The system has not undergone significant R&D or testing with metal targets.
  - **Ferrous metal the size of a single razor blade** – **UNKNOWN**; The system has not undergone significant R&D or testing with metal targets.
  - **Plastic the size of a plastic toothbrush handle (i.e., cylinder 1/4 inch diameter by 4 inches long)** – **YES**; Initial imaging results indicate that objects of this size should be able to be detected.
- **Scanning does not require contact with the subject's skin** – **YES** (see Figure 2)
- **Accommodate subjects up to the 95th percentile in girth** – **NO**; In its current design the system cannot accommodate those subjects. Future R&D stages would involve a redesign, but the tentative plan was to have a new system with a 2' inner diameter, which would be inadequate.

- **Device is stowable when not in use** – **NO**
- **Easy to use and provide intuitively understandable results** – **UNKNOWN**; The user interface for the system has not been developed yet.
- **Cost similar to the $6,000 now paid for metal detection portals** – **NO**; It is highly unlikely that a system that requires advanced multi-channel spectrometers would be able to be sold at this price point.
- **Scan times of several tens of seconds per subject** – **NO**; The current scan time would need to be improved by a factor of 10.

6.2 NIJ QM Project Status

The QM project has suffered from schedule and work efficiency issues due to organizational laboratory moves and the loss of key personnel. The project moved from the QM offices in San Diego to Morpho Detection offices in Santa Ana, CA. In addition, the previous principal investigator left the company and the project around the same time. Much of the technical and programmatic understanding of the project left with the PI. As a result, the QM has worked to replace staff and resume the work when it was possible, but there was undoubtedly a loss in efficiency due to the R&D learning curve and lack of momentum.

QM provided a rough cost and schedule estimate for the remaining work to develop the system to an advanced prototype suitable for field testing by a third party. The SSBT CoE, then revised that estimate based on its observations of the project and RDT&E experience (additional details can be found in Section 4.1 Programmatic):

- Cost Estimate (includes burdens): $1.2 – 2M (basic research); $0.9 – 1.3M (prototype)
- Schedule Estimate ~2 yrs (basic research); 1 – 2 yrs (prototype)

6.3 Criminal Justice Technology Need

Based on the survey results from the limited TWG practitioner group, there continues to be a Medium-High priority criminal justice technology need for Contraband Detection that is able to detect both metallic and non-metallic objects concealed on or in a person in an affordable manner. This technology need was tied for the fourth highest rated need out of 18 different ones. A companion report prepared by the SSBT CoE details contraband screening systems currently on the market with the ability to detect non-metallic contraband and contraband concealed in body cavities.[6] Of the fifteen different systems covered in that report, only one has the ability to detect both non-metallic and body cavity contraband. Therefore, there still remains a need for additional investments by NIJ (although other efforts beyond R&D would be beneficial, see Section 6.4 EFT vs. Other Technology Approaches).

The QM team developed a working set of operational requirements at the start of their project.

- *Detection Goals:*
  - *Nonferrous metal the size of a .22 caliber bullet*
  - *Ferrous metal the size of a single razor blade*
  - *Plastic the size of a plastic toothbrush handle (i.e., cylinder 1/4 inch diameter by 4 inches long)*
- *Scanning does not require contact with the subject's skin*
- *Accommodate subjects up to the 95th percentile in girth*
- *Device is stowable when not in use*
- *Easy to use and provide intuitively understandable results*
- *Cost similar to the $6,000 now paid for metal detection portals*
- *Scan times of several tens of seconds per subject*

Based on the survey results, future projects should consider modifying the requirements as follows (red = more requirements, green = less):

- **Reduce** the size of the detection goals for both metal and non-metal objects, such as condoms containing powders or pills or cell phone SIM cards.
- **Lessen** the requirement on portability to allow for fixed walk-through portal scanners.
- Include a privacy requirement for the image output.
- **Lessen** the requirement that a system must detect both metallic and non-metallic objects within body cavities.
- **Lessen** the requirement that a system must scan the entire body and allow for systems that scan only the mid-lower torso of a person.
- **Include** the following materials as explicit targets to be detected:
  - Explosives
  - Baggies or packets of powders (e.g., drugs)
- **Include** a minimum detect rate requirement for targets:
  - Plastic – 93%
  - Ferrous Metals – 96%
  - Nonferrous Metals – 91%

Taking into account these revised requirements, the QM BCS system's future viability becomes more uncertain. Lessening the requirement for the device to be stowable and be able to detect metallic objects improves the system's status, but the other requirement changes would introduce significant additional R&D and T&E to determine its viability. The QM system has not undergone even basic quantitative performance testing with plastic objects of the original threshold (i.e., toothbrush handle), let alone smaller objects like those proposed in the revised set above. In addition, explosives and powder testing has not been considered. While the system might eventually meet these requirements, extensive testing remains, the duration of which would probably extended the proposed follow-on schedule an additional 6 – 12 months.

6.4 EFT vs. Other Technology Approaches

To date, the only known technologies for body cavity screening of non-metallic contraband, with the potential for criminal justice applications, are EFT and low dose transmission x-ray imaging. EFT has potential, as demonstrated by QM in this project, but there are still many fundamental technical questions and challenges that need to be addressed before it is suitable for operational use. It is important that NIJ and the criminal justice community couch R&D investments and technology needs in terms of the desired operational capability/benefit and not explicitly specifying the technical method of arriving at those capabilities.

One area that warrants further investigation by NIJ is low dose transmission x-ray technologies. In transmission x-ray scanning, materials of different composition and density absorb or reflect X-rays differently. Bones and metal objects are better able to block X-rays than soft tissue. This difference shows up on an image produced by x-rays passing through the subject to a detector. The image produced is then examined for contraband. Since transmission devices use X-rays that pass completely through the body, metallic and non-metallic contraband material concealed either on or inside the body have the potential of being detected.

Because of the ubiquity of x-ray technologies in the medical field, the engineering and safety issues involved are well documented and understood. In addition, the technology is cost effective because of those pre-existing markets. The exposure from a transmission x-ray scan for cavity contraband is the roughly the equivalent of one hour of background radiation at ground level, or 10 minutes at cruising altitude in an airplane.[7] Airplane crews deal with this level of exposure their entire careers. According to one criminal justice practitioner involved in the survey, the problem is that many state medical laws were written decades ago and classify any type of human x-ray device as a medical device that must be operated by a certified x-ray technician.[8] As a result, the adoption of x-ray technologies in other screening applications has been restricted. It would be beneficial to the criminal justice community if NIJ examined this technology field and the viability of adopting low dose transmission x-ray technologies in a more wide-spread contraband screening application from an engineering and safety perspective as well as a regulation and policy perspective.

7.0 RECOMMENDATIONS

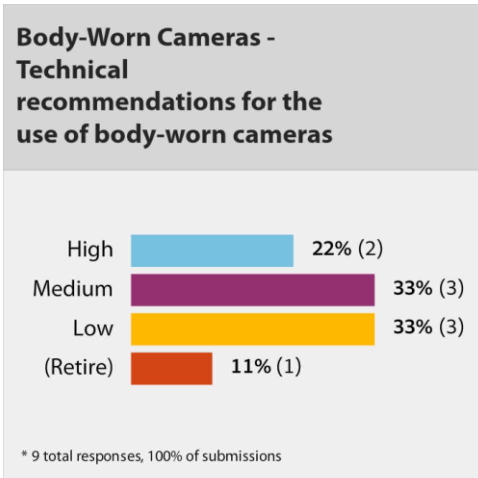
Based on the technology assessment of body cavity screening technologies, the SSBT CoE provides the following three recommendations to NIJ:

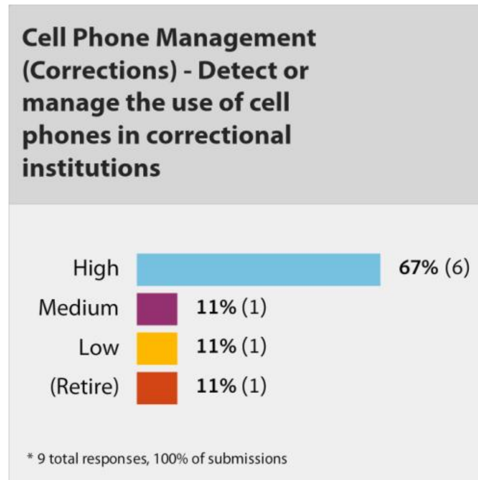
4. **NIJ should continue to pursue R&D of body cavity screening technologies capable of detecting non-metallic objects.** Based on the limited TWG survey, the technology need remains at a Medium-High priority. There are few commercial options for meeting this technology need. Therefore, this topic should remain a key priority for future NIJ R&D funding. However, the topic should be left agnostic to the technology approach used to deliver the practitioner capability.

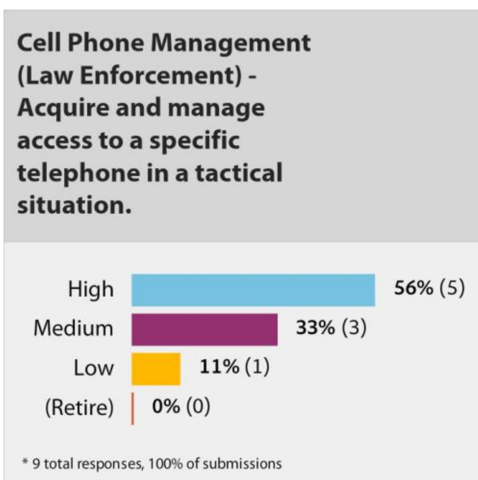
5. **NIJ should investigate regulation and policy issues regarding the use of low dose transmission x-ray technologies in criminal justice contraband screening.** This technology is known to be able to detect non-metallic objects concealed in body cavities. Changes in regulations at the state and federal levels could allow for the technology need to be met by a low-cost technology that is already well established. Studies on the topic from a technical and policy perspective could help educate criminal justice agencies and legislatures.

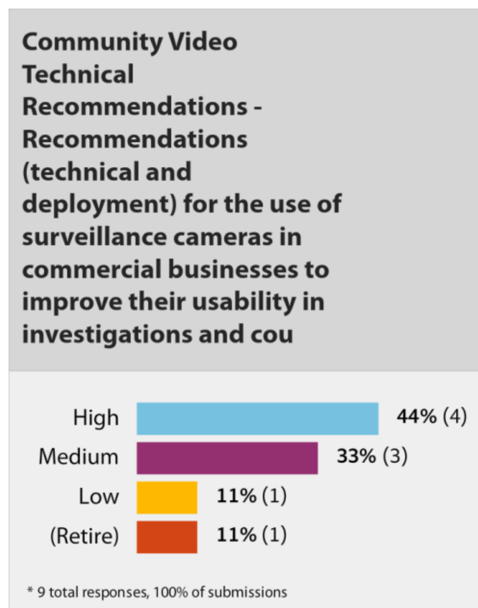
6. **There does not exist a compelling case to continue funding the current prototype system and QM team.** Although the QM project has made progress in tackling fundamental technical challenges, there remain many technical, programmatic, and operational challenges in the follow-on stages. For this technical topic, NIJ should return to a competitive solicitation to allow alternative performers and technologies.

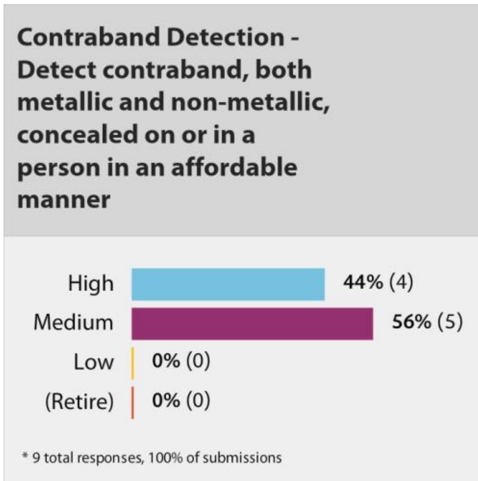
APPENDIX A: CRIMINAL JUSTICE PRACTITIONER QUESTIONNAIRE – SENSORS & SURVEILLANCE TECHNOLOGY NEEDS PRIORITIES

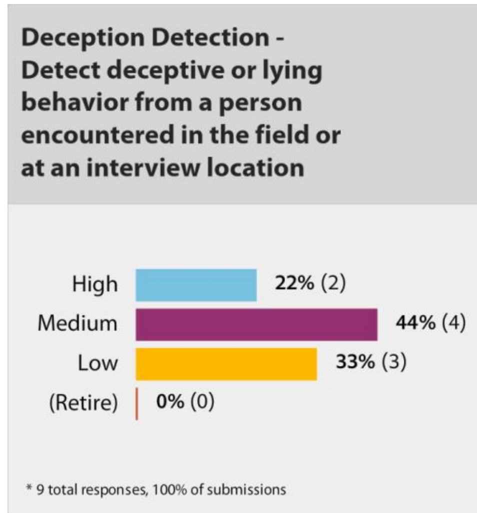

Body-Worn Cameras - Technical recommendations for the use of body-worn cameras
High
22% (2)
Medium
33% (3)
Low
33% (3)
(Retire)
11% (1)
* 9 total responses, 100% of submissions

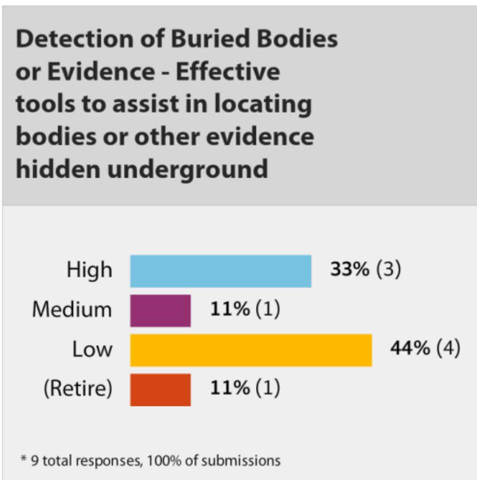

Cell Phone Management (Corrections) - Detect or manage the use of cell phones in correctional institutions
High
67% (6)
Medium
11% (1)
Low
11% (1)
(Retire)
11% (1)
* 9 total responses, 100% of submissions

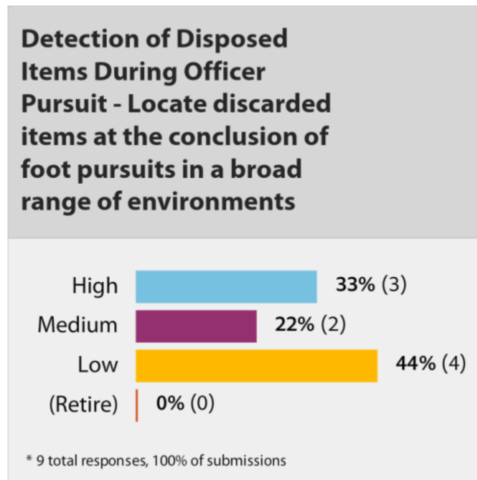

Cell Phone Management (Law Enforcement) - Acquire and manage access to a specific telephone in a tactical situation.
High
56% (5)
Medium
33% (3)
Low
11% (1)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

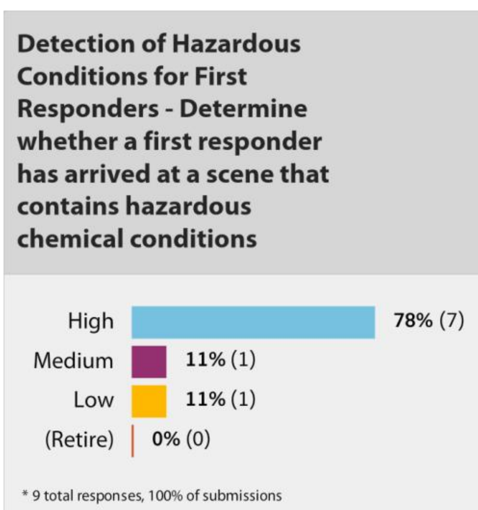

Community Video Technical Recommendations - Recommendations (technical and deployment) for the use of surveillance cameras in commercial businesses to improve their usability in investigations and cou
High
44% (4)
Medium
33% (3)
Low
11% (1)
(Retire)
11% (1)
* 9 total responses, 100% of submissions

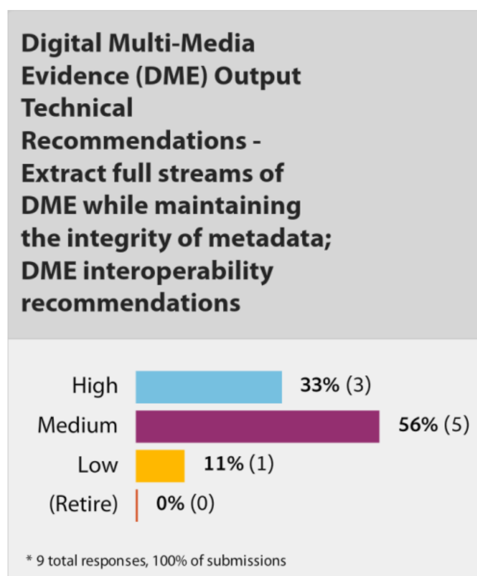

Contraband Detection - Detect contraband, both metallic and non-metallic, concealed on or in a person in an affordable manner
High
44% (4)
Medium
56% (5)
Low
0% (0)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

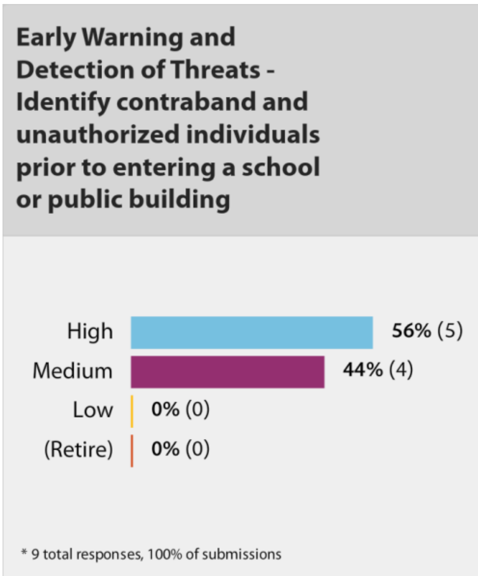

Deception Detection - Detect deceptive or lying behavior from a person encountered in the field or at an interview location
High
22% (2)
Medium
44% (4)
Low
33% (3)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

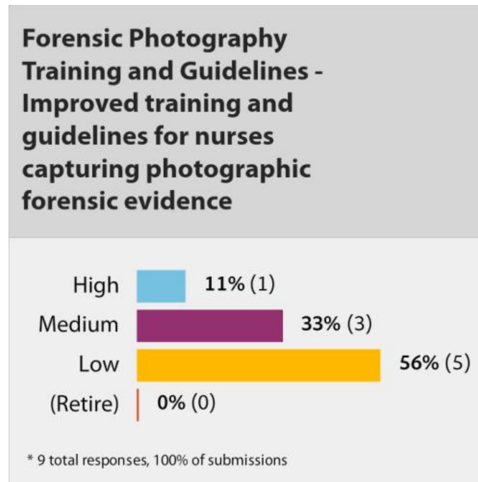

Detection of Buried Bodies or Evidence - Effective tools to assist in locating bodies or other evidence hidden underground
High
33% (3)
Medium
11% (1)
Low
44% (4)
(Retire)
11% (1)
* 9 total responses, 100% of submissions

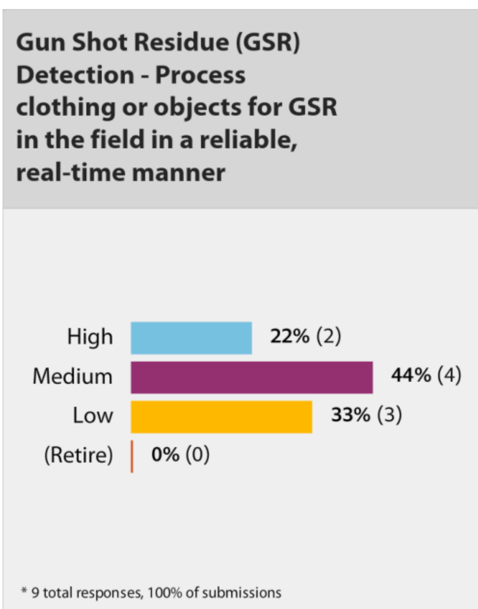

Detection of Disposed Items During Officer Pursuit - Locate discarded items at the conclusion of foot pursuits in a broad range of environments
High
33% (3)
Medium
22% (2)
Low
44% (4)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

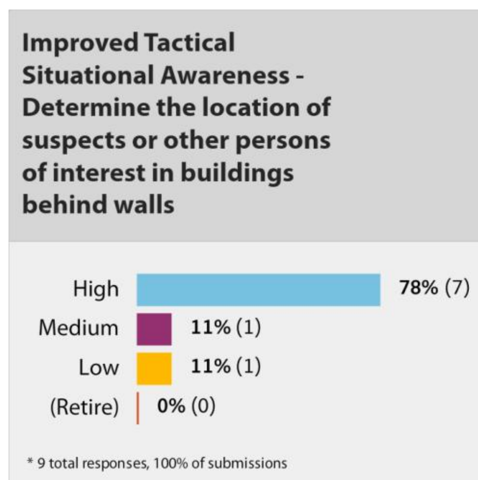

Detection of Hazardous Conditions for First Responders - Determine whether a first responder has arrived at a scene that contains hazardous chemical conditions
High
78% (7)
Medium
11% (1)
Low
11% (1)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

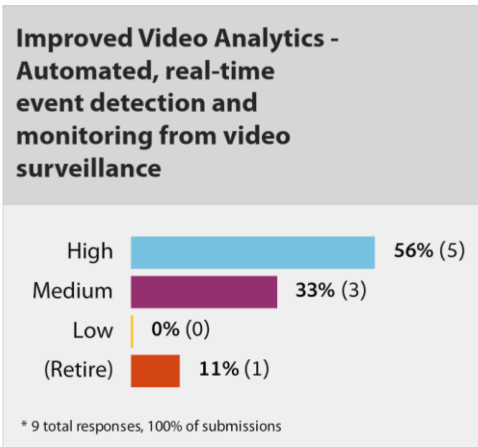

Digital Multi-Media Evidence (DME) Output Technical Recommendations - Extract full streams of DME while maintaining the integrity of metadata; DME interoperability recommendations
High
33% (3)
Medium
56% (5)
Low
11% (1)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

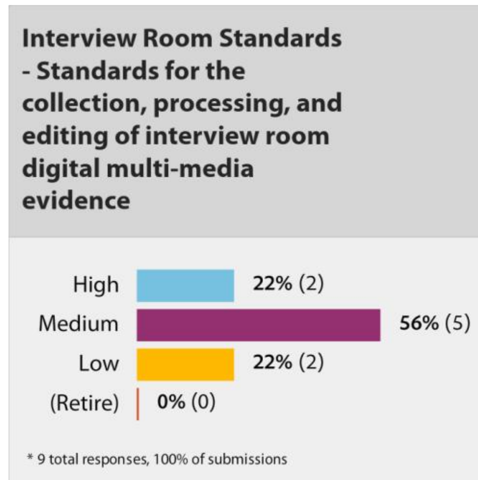

Early Warning and Detection of Threats - Identify contraband and unauthorized individuals prior to entering a school or public building
High
56% (5)
Medium
44% (4)
Low
0% (0)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

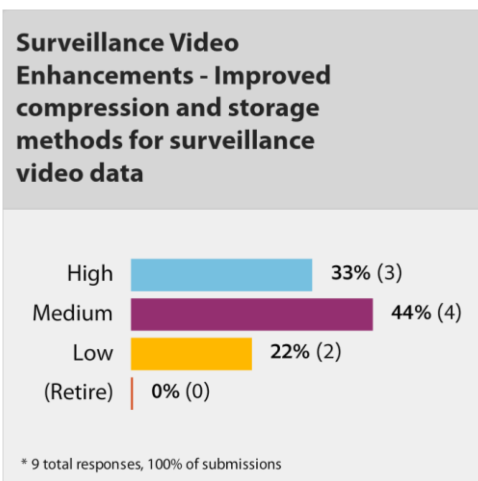

Forensic Photography Training and Guidelines - Improved training and guidelines for nurses capturing photographic forensic evidence
High
11% (1)
Medium
33% (3)
Low
56% (5)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

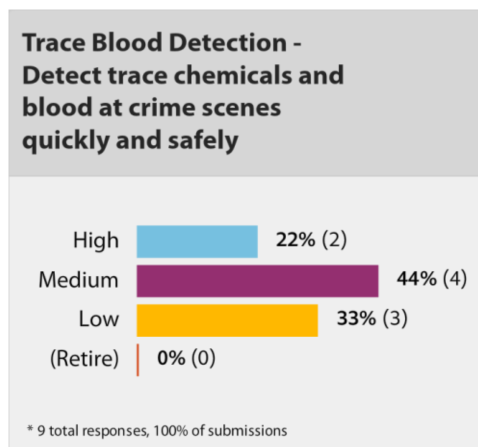

Gun Shot Residue (GSR) Detection - Process clothing or objects for GSR in the field in a reliable, real-time manner
High
22% (2)
Medium
44% (4)
Low
33% (3)
(Retire)
0% (0)
* 9 total responses, 100% of submissions


Improved Tactical Situational Awareness - Determine the location of suspects or other persons of interest in buildings behind walls
High
78% (7)
Medium
11% (1)
Low
11% (1)
(Retire)
0% (0)
* 9 total responses, 100% of submissions


Improved Video Analytics - Automated, real-time event detection and monitoring from video surveillance
High
56% (5)
Medium
33% (3)
Low
0% (0)
(Retire)
11% (1)
* 9 total responses, 100% of submissions


Interview Room Standards - Standards for the collection, processing, and editing of interview room digital multi-media evidence
High
22% (2)
Medium
56% (5)
Low
22% (2)
(Retire)
0% (0)
* 9 total responses, 100% of submissions


Surveillance Video Enhancements - Improved compression and storage methods for surveillance video data
High
33% (3)
Medium
44% (4)
Low
22% (2)
(Retire)
0% (0)
* 9 total responses, 100% of submissions


Trace Blood Detection - Detect trace chemicals and blood at crime scenes quickly and safely
High
22% (2)
Medium
44% (4)
Low
33% (3)
(Retire)
0% (0)
* 9 total responses, 100% of submissions

APPENDIX B: ACRONYMS, ABBREVIATIONS, AND REFERENCES

B.1 Acronyms and Abbreviations

ACRONYM	DESCRIPTION
BCS	Body Cavity Screening
CoE	Center of Excellence
DOJ	Department of Justice
EFT	Electric Field Tomography
HSR	Human Subject Research
NIJ	National Institute of Justice
NLECTC	National Law Enforcement and Corrections Technology Center
QM	Quantum Magnetics
R&D	Research and Development
Rx	Receiver
SRD	System Requirements Definition
SSBT	Sensor, Surveillance, and Biometric Technologies
T&E	Test and Evaluation
TRL	Technology Readiness Level
TWG	Technology Working Group
Tx	Transmitter

B.2 References

[1] Erik Magnuson, Morpho Detection; *Compact, Low-Cost Body Cavity Screening Device;* Final Report for NIJ Award 2007-DE-BX-K001, https://www.ncjrs.gov/pdffiles1/nij/grants/241685.pdf (January 2013).

[2] Erik Magnuson, Morpho Detection; *Compact, Low-Cost Body Cavity Screening Device;* Final Report for NIJ Award 2011-IJ-CX-K001 (Pending Release).

[3] Department of Defense, *Technology Readiness Assessment (TRA) Guidance*, http://www.acq.osd.mil/ddre/publications/docs/TRA2011.pdf (April 2011).

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