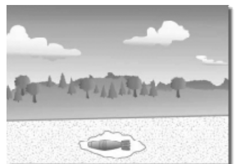
1

Welcome – Thanks for joining us.
ITRC's Internet-based Training Program

Survey of Munitions Response Technologies



Survey of Munitions Response Technologies (UXO-4, 2006)

This training is co-sponsored by the US EPA Technology Innovation and Field Services Division (TIFSD)

This training introduces state regulators, environmental consultants, site owners, and community stakeholders to *Survey of Munitions Response Technologies* (UXO-4, 2006), created by the ITRC's Unexploded Ordnance Team in partnership with the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP). The document provides an overview of the current status of commercially-available technologies in common usage for munitions response actions, and, where possible, assess and quantify their performance capabilities. The document includes detailed findings from three separate surveys: (1) an assessment of technology implementation prevalence, (2) an evaluation of Geophysical Prove-Out (GPO) characteristics, and (3) an analysis of technology performance based on GPO and standardized test site results. The document also provides background information about technologies used in munitions response actions, as well as information about advanced technologies.

This training course is intended for an intermediate to advanced audience and assumes an understanding of technologies and phases of munitions response. Background information on some of the topics can be found in *Munitions Response Historical Records Review* (UXO-2, 2003) and *Geophysical Prove-Outs for Munitions Response Projects* (UXO-3, 2004), and their associated Internet-based training courses (available from *http://www.itrcweb.org/ibt.asp#mr_uxo*). This training course focuses on the major take-home conclusions of the *Survey of Munitions Response Technologies* (UXO-4, 2006) and provides an understanding of the performance capabilities of available technologies under real-world site conditions.

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (www.clu-in.org)

ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419

ITRC Disclaimer and Copyright

Here's the lawyer's fine print. I'll let you read it yourself, but what it says briefly is:

•We try to be as accurate and reliable as possible, but we do not warrantee this material.

•How you use it is your responsibility, not ours.

•We recommend you check with the local and state laws and experts.

•Although we discuss various technologies, processes, and vendor's products, we are not endorsing any of them.

•Finally, if you want to use ITRC information, you should ask our permission.

3

ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization (ECOS)
- Network
  - State regulators
    - All 50 states and DC
  - Federal partners

    DOE DOD EPA
  - ITRC Industry Affiliates Program (IAP)
  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Technical and regulatory guidance documents
  - Internet-based and classroom training

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

4

ITRC Course Topics Planned for 2010 – More information at www.itrcweb.org

Popular courses from 2009

- Decontamination and Decommissioning of Radiologically-Contaminated Facilities
- Enhanced Attenuation of Chlorinated Organics
- In Situ Bioremediation of Chlorinated Ethene - DNAPL Source Zones
- LNAPL Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface
- LNAPL Part 2: LNAPL Characterization and Recoverability
- Perchlorate Remediation Technologies
- Performance-based Environmental Management
- Phytotechnologies
- Protocol for Use of Five Passive Samplers
- Quality Consideration for Munitions Response
- Survey of Munitions Response Technologies
- Determination/Application of Risk-Based Values
- Use of Risk Assessment in Management of Contaminated Sites

New in 2010

- Attenuation Processes for Metals & Radionuclides
- LNAPL Part 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
- Mining Waste
- Remediation Risk Management: An Approach to Effective Remedial Decisions and More Protective Cleanups

ITRC 2-day Classroom Training: Vapor Intrusion Pathway

More details and schedules are available from www.itrcweb.org under “Internet-based Training” and “Classroom Training.”

5

Survey of Munitions Response Technologies

Logistical Reminders

- Phone line audience
  - ✓ Keep phone on mute
  - ✓ *6 to mute, *7 to un-mute to ask question during designated periods
  - ✓ Do NOT put call on hold
- Simulcast audience
  - ✓ Use ? at the top of each slide to submit questions
- Course time = 2¼ hours

Presentation Overview

Introduction and course overview

1. State of Detection Technologies: an Overview

2. Interpreting Detection System Performance

Question and Answer Break

3. Case Studies

Links to additional resources

Your feedback

Question and Answer Break

No associated notes.

Meet the ITRC Instructors

Ken Vogler
Colorado Dept. of Public Health and Environment
Denver, Colorado
303-692-3383
ken.vogler@state.co.us

Rose Weissman
Kleinfelder
Newburgh, New York
845-567-6530
rweissman@kleinfelder.com

Jim Pastorick
UXO Pro, Inc.
Alexandria, Virginia
703-548-5300
jim@uxopro.com

Ken Vogler has been with the Hazardous Materials and Waste Management Division since 2002. Prior to that he worked in hydrology and environmental consulting for 20 years both in the United States and overseas. He currently provides regulatory oversight on a munitions response site at the former Rocky Mountain Arsenal in Colorado. Mr. Vogler has a B.S. degree from Colorado State University and an M.S. degree from the University of Arizona. He is a registered Professional Engineer in Colorado and Oklahoma.

Rose Weissman is a Senior Project Manager in Newburgh, New York with Kleinfelder with project focus including Department of Energy decommissioning of a legacy research and development facility, public utilities environmental management, retail gasoline operations, and manufacturing environmental compliance. Since 1988, Rose has worked as an environmental professional on RCRA waste management and facility investigations, site assessment, investigation, and remediation, UST management, explosives manufacturing, UXO remediation, and multimedia permitting and compliance. She has worked extensively with the US EPA on Region 2 priority sites in the continental US and Caribbean, as well as with the Army Corps of Engineers in remote areas of Alaska assessing military lands to be returned to Native Alaskan Corporations. She has been qualified as an expert in the areas of site assessment, site investigation, remediation, and UST failure in numerous litigations in New York, New Jersey, and Pennsylvania. Rose is a member of the ITRC Radionuclides team and ITRC UXO team, has been active in community outreach programs and environmental awareness during the course of her professional career, and was awarded a Paul Harris Fellowship for outstanding community service and her work with inner-city youth by the Paterson Rotary Club. She earned a bachelor's degree in biology from Felician College in Lodi, New Jersey in 1988.

Jim Pastorick is President of UXO Pro, Inc., in Alexandria, Virginia. UXO Pro provides technical support to state regulators and other non-Department of Defense organizations on munitions and explosives of concern/unexploded ordnance (MEC/UXO) project planning, management, and quality assurance. Jim is a former Navy Explosive Ordnance Disposal (EOD) officer. Since leaving the Navy, he has worked as the Senior UXO Project Manager for UXB International, Inc. and IT Corporation prior to starting his company in 1999. Jim has served on committees of the National Research Council Board on Army Science and Technology. He is a member of the ITRC UXO team and an instructor on the team's ITRC Internet-based training courses. Before attending college, he served as a Navy enlisted man in the SEABEES. He worked as a photographer for The Columbia Record prior to reentering the Navy as a diver and EOD officer. Jim earned a bachelor's degree in journalism from University of South Carolina in Columbia, South Carolina in 1980 and graduated from the U.S. Naval School of EOD in Indian Head, Maryland in 1986.

Tim Deignan is a geophysicist at Shaw Environmental & Infrastructure Group beginning in November 2009. Previously, he was the Discipline Lead for geophysics at Tetra Tech EC, Inc. in Lakewood, Colorado, where he worked from 1988 to 2009 in the environmental geophysical field. He is routinely involved in survey planning, data acquisition, processing, and analysis and interpretation of geophysical data, as well as the development of sensor and positioning systems and platforms. In performing and managing geophysical surveys for MEC projects since 1994, he has been provided the unique opportunity to interact with client, regulatory, and industry personnel in the continued development of the optimum quality processes' for MEC projects. Tim has been a member of the ITRC UXO team since 2003/2004, and has provided input for several ITRC guidance documents. He has also been an invited speaker for the SERDP/ESTCP conferences, as well as the bi-annual UXO Forum. Tim earned a bachelor's degree in geophysical engineering from the Colorado School of Mines in Golden, Colorado in 1988 and is also a registered Professional Geophysicist in the state of California.

7

Importance of Munitions Response Technology Selection

- A technology's effectiveness will determine
  - Amount of munitions removed
  - Productivity
  - Cost of a project
  - Degree of confidence in the response action
- No single best technology can be recommended for all applications

Selection of technology for a munitions response action is site specific…such things as the type, size, and depth of munitions items, site terrain, site vegetation, and presence of magnetic geology must be considered.

8

Advances in Munitions Response Technology

- Technology has evolved significantly over the past decade
  - Planning software created
  - Geolocation and navigation tools more accurate and reliable
  - Sensor and platform design and performance evolving
  - Understanding of how to deploy munitions response technologies in the field is increasing
- Ability of a response action to successfully detect and remove munitions items in the field has increased

Government-developed standardized software and contractor-developed (proprietary) software.

Government-developed: Visual Sampling Plan (VSP) & Geosoft Oasis montaj

VSP software can be downloaded (free) at: http://dqo.pnl.gov/VSP/

9

Survey of Munitions Response Technologies Document

- Survey of Munitions Response Technologies (UXO-4)
  http://www.itrcweb.org/Documents/UXO-4.pdf

Survey of Munitions Response Technologies

Prepared by:

The Environmental Security Technology Certification Program (ESTCP)
The Interstate Technology & Regulatory Council (ITRC)
The Strategic Environmental Research and Development Program (SERDP)

June 2006

ITRC guidance document from the UXO team are available to download at www.itrcweb.org under “Guidance Documents” and “Unexploded Ordnance” or directly at http://www.itrcweb.org/Documents/UXO-4.pdf

10

Survey of Munitions Response Technologies Document

Background

- Developed jointly by
  - Strategic Environmental Research and Development Program (SERDP)
  - Environmental Security Technology Certification Program (ESTCP)
  - Interstate Technology & Regulatory Council (ITRC) Unexploded Ordnance Team
- Need to establish a common and widely accepted understanding of technology performance capabilities and limitations, as well as the conditions that affect them
- Document discusses technologies for
  - Site preparation, munitions detection and discrimination, filler material identification, munitions removal, and treatment

No associated notes.

11

Survey of Munitions Response Technologies Document

Background (continued)

- Survey
  - Current state of the practice
  - Performance capabilities and limitations of detection technologies
    - Controlled test sites
    - “Real-world” munitions response sites
- All data analysis performed by scientists at Institute for Defense Analyses (IDA) and Mitretek
- Companion report provides greater analytical detail
  - "Interpreting Results from the Standardized UXO Test Sites" available from the Defense Technical Information Center (DTIC) Scientific and Technical Information Network (STINET) (http://stinet.dtic.mil/)

Current state of the practice survey: 66 response actions at 44 sites

Controlled test sites: Aberdeen and Yuma Proving Grounds

These are highly controlled

Internet link to companion report: "Interpreting Results from the Standardized UXO Test Sites" available from the Defense Technical Information Center (DTIC) Scientific and Technical Information Network (STINET)

12

Survey of Munitions Response Technologies Document

Goals

- Provide an overview
  - Current status of technologies
  - Evaluate and quantify their performance capabilities
- Help regulators and implementers understand technologies
  - Current capabilities
  - Applications
  - Limitations
- Facilitate communication regarding technology application to specific site conditions
- Assist a project team in selecting the most appropriate technology for a particular action

Analysis of technologies **as they are used** …(one contractor chose to do X, another chose to do Y, one contractor processed this way, one processed that way)...not a specific test of a detection sensor.

Stress what the document is, and what is isn't: deployed systems, not sensor capabilities

The performance seen in this analysis is affected not only by the capabilities of the sensors, but how they are implemented by the protocols used by the various contractors, and how the contractors gather and interpret their data. This includes the platform and the target methodologies.

13

Survey of Munitions Response Technologies Document

Limitations

- Limited mainly to commercially currently-available technologies
- Provides data from real-world settings, not a test-lab setting
- Topics not covered in document
  - Regulatory process or policy
  - Explosive safety issues
  - Chemical warfare materials
  - Munitions constituents
- Not intended to prescribe or endorse specific technology solutions
- Not designed or intended to predetermine cleanup decisions

No associated notes.

14

Survey of Munitions Response Technologies Document

Contents

Chapters listed in larger and bold font are what this training focuses on.

15

Training Goals

- Introduce and encourage use of the *Survey of Munitions Response Technologies* document by regulators, implementers, and researchers
- Provide a "higher-level" or "follow-on" training to previous ITRC UXO Team guidance documents and training efforts
  - UXO -1: Breaking Barriers to the Use of Innovative Technologies: State Regulatory Role in Unexploded Ordnance Detection and Characterization Technology Selection (December 2000)
  - UXO-2: Munitions Response Historical Records Review (November 2003)
  - UXO-3: Geophysical Prove-Outs for Munitions Response Projects (November 2004) and associated internet based training course
  - "Site Investigation and Remediation" internet based training course
  - "UXO Basic Training" classroom training course
- Provide participants with "take home" messages regarding the detection technologies being used on sites and the factors that affect their performance

ITRC UXO Team guidance documents and training available for download at:

http://www.itrcweb.org/teamresources_19.asp

16

Training Goals (continued)

- Refresher on munitions response detection technologies and processes
- What detection technologies are being used in the field today
- How detection technologies performed against each other
  - Highly controlled conditions (test sites)
  - Real world conditions (actual sites)
- What are the strengths and limitations of detection technology systems
- Things to consider when implementing technologies based on experiences at case studies

Not drawing conclusions from performances of entities, but looking at the technology system, how it is used, and the variability of that effectiveness.

17

Training Limitations

- Focus of training is on portions of document pertaining to research conducted on detection technologies
- Assumes a basic understanding of geophysics for munitions response technologies
- Glossary of terms and acronyms included in document

Survey of Munitions Response Technologies

Prepared by:

The Environmental Security Technology Certification Program (ESTCP)
The Interstate Technology & Regulatory Council (ITRC)
The Strategic Environmental Research and Development Program (SERDP)

June 2006

The publication of this document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency. Mention of specific product names or vendors does not constitute an endorsement by any of the authoring organizations.

No associated notes.

Training Presentation Overview

- Module 1: Detection Technologies – Overview and Current State of the Practice
- Module 2: Interpreting Detection System Performance
- Module 3: Case Studies


Survey of Munitions Response Technologies

SERDP

ESTCP

ITRC

Prepared by:

The Environmental Security Technology Certification Program (ESTCP)
The Interstate Technology & Regulatory Council (ITRC)
The Strategic Environmental Research and Development Program (SERDP)

June 2006

The publication of this document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency. Mention of specific product names or vendors does not constitute an endorsement by any of the authoring organizations.

No associated notes.

19

Survey of Munitions Response Technologies

MODULE 1:

Detection Technologies –

Overview & Current State of the Practice

Information culled from Chapter 3 of the "Survey of Munitions Response Technologies Document"

20

Module 1 Learning Objectives

- Overview of munitions response detection
  - Processes
  - Operations
  - Technologies
- Current state of the practice for munitions response detection technologies
  - What is being used?
  - What are the current usage trends?

Trends in equipment usage broken down into three operations: “sweep”, “mapping”, “reacquisition”

State of the practice survey designed to analyze technology selection during various phases of a cleanup project.

By current we mean…at the time the study was performed.

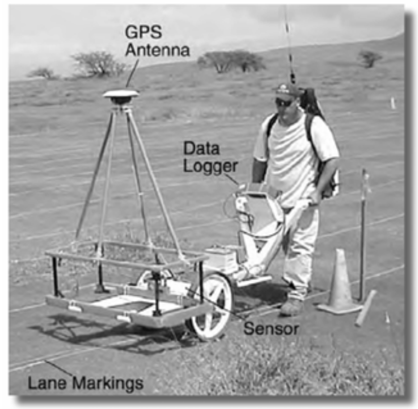
Performance and metrics in Module 2…this is what technology is available, what is being used, and when

Goal: Consider all available technologies…determine most appropriate based on site conditions and project goals and objectives.

21

Overview of Munitions Response Detection
Processes

- Mag and Flag
- Digital Geophysical Mapping (DGM)



Mag and flag: A survey process in which field personnel use hand-held geophysical instruments to manually interpret anomalies and surface-mark them with non-metallic flags for excavation.

Digital Geophysical Mapping: Any geophysical system that digitally records geophysical and positioning information.

Figure 3-5 (on left): Mag-and-flag survey
Figure 3-20 (on right): Cart-mounted system with EM61 EMI sensor (DGM)

Overview of Munitions Response Detection

Operations

- Munitions-Sweep
  - Systematic real-time search of an area to locate surface or subsurface anomalies
- Munitions-Mapping
  - Collecting and processing geo-referenced digital geophysical mapping data to identify subsurface anomalies
- Munitions-Reacquisition
  - Locating subsurface anomalies previously detected through sweep or mapping

Munitions detection technology performs three types of operations…

Munitions-Sweep: surface clearance and mag-and-flag subsurface clearance

Same detection technology may be used for multiple operations

Important note: terminology shown here is consistent with the terminology used in the document for purposes of communicating the results of the “State of the Practice Survey”

23

Overview of Munitions Response Detection
Technologies

- Elements of munitions detection systems
  - Geophysical sensor
  - Survey platform
  - Positioning and navigation system
  - Data-processing system

A munitions detection system is composed of four main elements, regardless of its operation/application…

24

Overview of Munitions Response Detection Technologies

Geophysical Sensors

- Magnetometer - Passive sensor that detects ferrous metals
  - Flux-gate
  - Cesium Vapor (CV)
- Electromagnetic Induction (EMI) - Active sensor that detects all metals
  - Operated in time domain (TD)
  - Frequency domain (FD)
- Dual-Sensor Systems
  - Magnetometer and EMI on a single platform

[3.3.1]

For further information on detection technology geophysical sensors, the audience is referred to Section 3.3.1 of "Survey of Munitions Response Technologies" document

Common example of a hand-held EMI is metal detector used at the beach.

Top picture (Figure 3.1): Schonstedt magnetometer

Bottom picture (Figure 3.1): Geonics EM61-MK2 EMI

Important note: As illustrated in the top figure, sometimes the operator is everything but the sensor (they are the survey platform, the positioning and navigation system, and the data processing system).

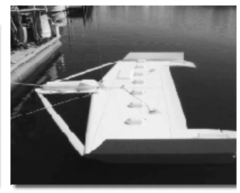
25

Overview of Munitions Response Detection Technologies

Survey Platforms

- Hand-held
- Man-portable
- Cart-mounted
- Towed-array
- Airborne
- Underwater




[3.3.2]

For further information on detection technology survey platforms, the audience is referred to Section 3.3.2 of “Survey of Munitions Response Technologies” document.

Hand-held and man-portable also referred to as “hand-carried”

Underwater mapping platforms are currently under development, but none are commercially available yet.

Choice of survey platform dictated by: type of munitions detection operation, type of sensor deployed, and site to be surveyed.

Figures (clockwise from top left):

Figure 3-18: hand-held analog electromagnetic systems

Figure 3-19: man-portable platform

Figure 7-10: assembled marine sensor platform shown floating beside the tow boat

Figure 3-22: helicopter-based survey

Figure 3-20: cart-mounted system with cesium-vapor magnetometer sensor

Overview of Munitions Response Detection Technologies

Survey Platforms (continued)

- Woman-portable

Man-portable synonymous with woman-portable!

Photo taken during ITRC UXO Team site-visit to Limestone Hills, Montana, August 2006 (detection technology demonstration at Montana Army National Guard cleared UXO site)

27

Overview of Munitions Response Detection Technologies

Positioning and Navigation Systems

- Positioning and navigation equipment
  - Laser-based systems
  - Differential GPS
  - Fiducial positioning
  - Ropes and lanes
  - Track indicators

[3.3.3-3.3.4]

For further information on detection technology positioning equipment and navigation systems, the audience is referred to Section 3.3.3 and 3.3.4of “Survey of Munitions Response Technologies” document.

Positioning Equipment: Needed in digital geophysics (such as digital geophysical mapping or DGM); Determine sensor’s geographic location at each data point recorded

Navigation Systems: guides the system operator over the area of interest to be mapped; whether or not a preplanned course is being correctly followed

Not a comprehensive list…

Figure 3-23: Ropes navigation in a geophysical survey area

28

Overview of Munitions Response Detection Technologies

Data Processing Systems

- Convert raw survey data into meaningful position-correlated data
- Outputs include maps of interpreted data and databases of anomaly selections
- Analytical tools
  - Geosoft Oasis Montaj Utilities
  - Surfer
  - Proprietary, instrument-specific (e.g., Geonics dat61MK2, Geometrics MagMap2000)

[3.3.4]

For further information on detection technology data processing systems, the audience is referred to Section 3.3.4 of “Survey of Munitions Response Technologies” document.

Analytical Tools:

Oasis Montaj: by Geosoft, Inc.; widely accepted and used to manage data

Geosoft Oasis montaj software can be downloaded (free viewer) at: http://www.geosoft.com/pinfo/oasismontaj/index.asp

29

Current State of the Practice Survey
Background

- 66 instrument evaluation studies at 44 munitions response sites from 2000-2005

Figure 3.2 from Survey of Munitions Response Technologies (UXO-4)

Now that we have provided an overview…let’s look at what is being used and where…an understanding of what is being used and which instruments dominate in field applications

Figure 3.2: Locations of the instrument evaluation studies for 44 actual munitions response sites. There is wide geographic distribution.

Studies chosen based on availability of needed data and documentation

Current State of the Practice Survey

Background (continued)

- 44 different sites
- 66 different munitions response actions at the 44 sites
- 201 instruments considered and tested within the 66 response actions
- 4 instrument technology types
  - Flux-gate magnetometer
  - Cesium vapor magnetometer
  - Time Domain EMI
  - Frequency Domain EMI

Actions: EE/CA, TCRA, RI/SI, or RA

Approach was to catalog the geophysical instruments that were considered and tested in a GPO or equivalent evaluation and subsequently selected or recommended for production survey use. (After Action reports used if GPO not available)

Multiple actions at some sites: ex. - Engineering Evaluation/Cost Analysis and Time Critical Removal Action at Camp Swift, Texas

Multiple instruments within some actions

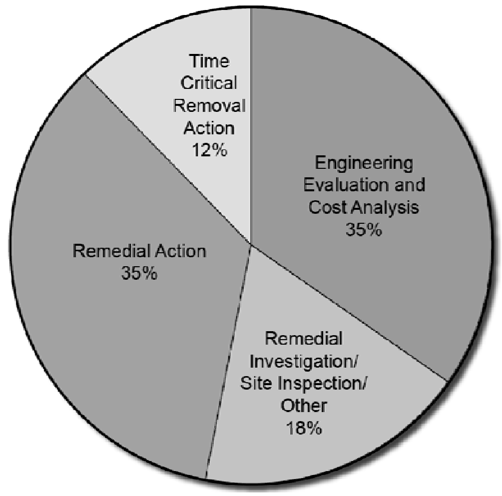
How many different instruments within the total 201?

31

Current State of the Practice Survey

Background (continued)

- Distribution of 66 munitions response actions evaluated by munitions response project phase



[Figure 3.2]

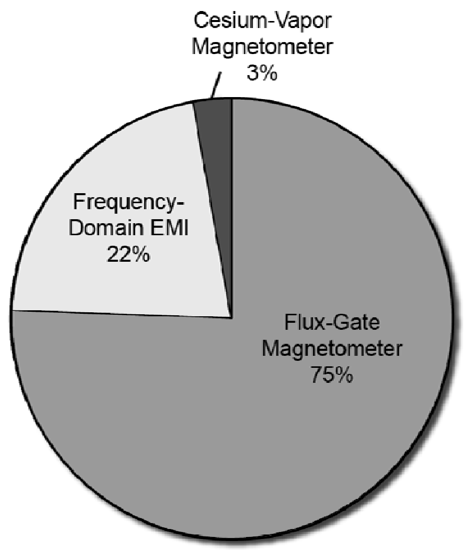
The 66 actions roughly equally weighted between the investigation phase (53% EE/CA and SI/RI) and cleanup phase (47% RA and TCRA).

Site-specific phase information can be found in Table 3-1 of the document.

32

Current State of the Practice Survey
Munitions Sweep Operations

- Instrument types selected for munitions sweep operations



[3.2.1]

Based on 37 instruments

Of the 66 response actions studied, 30 included munitions-sweep operations.

37 instruments were selected; 3 different types of sensor technologies

Figure shows breakout by sensor technology of those selected for munitions sweep operations.

Table 3-3 in document presents the currently available technologies for munitions sweep operations

As you can see a pretty large majority of the surveyed sites are using flux gate magnetometers for the initial sweep of the sites. Sweep operations are also commonly called mag and flag or mag and dig.

33

Current State of the Practice Survey

Munitions Sweep Operations

- Magnetometer technology selected in **25**
- Both EMI and magnetometer technology used in only **3**
- Schonstedt flux-gate magnetometer most common - selected in **25**
- Multiple instruments selected in **6**

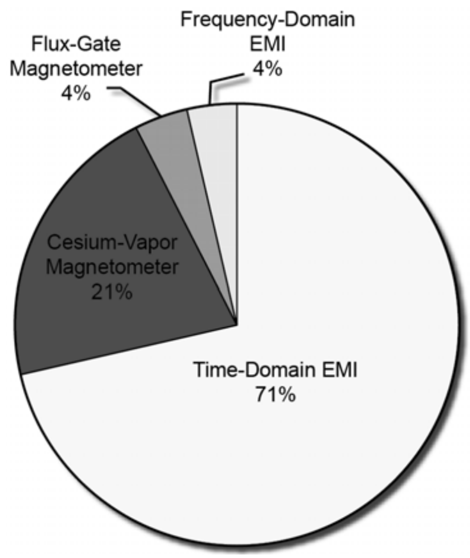
Of the 30 total munitions sweep actions….

34

Current State of the Practice Survey

Munitions Mapping Operations

- Instrument types selected for munitions mapping operations



[3.2.2]

80 instruments selected…

Figure shows breakout by instrument type of those selected for munitions mapping operations.

Table 3-5 in document presents the currently available technologies for munitions mapping operations

Large majority of sites reported using time domain EMI for geophysical mapping. This can be a function of a number project goals such as developing a permanent digital geophysical record of detected anomalies.

35

Current State of the Practice Survey

Munitions Mapping Operations

- Time-domain EMI used in **48**
  - Geonics EM61 and its variants (MK1, MK2, HH) most common time-domain EMI sensors
- Magnetometers used in **17**
  - **14** cesium vapor
  - **3** flux-gate
- Geometrics G858 cesium vapor most common magnetometer, used in **12 of 17**
- Frequency-domain EMI used in only **3**, and always with time-domain EMI

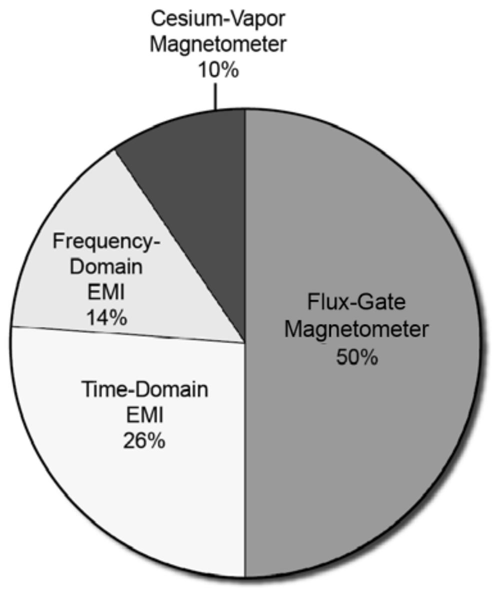
Of the 59 actions…

36

Current State of the Practice Survey

Munitions Reacquisition Operations

- Instrument types selected for munitions reacquisition operations



[3.2.3]

84 instruments selected

Figure shows breakout by instrument type of those selected for munitions reacquisition operations.

Table 3-7 in document presents the currently available technologies for munitions reacquisition operations

Finally at the re-acquisition stage of the surveyed projects, that is going back out in the field to re-acquire target geophysical anomalies, there is more distribution among the most common sensors with flux gate mag being reported at 50% of the surveyed sites.

Current State of the Practice Survey

Munitions Reacquisition Operations

- Magnetometer most common, used in **40**
  - **19** magnetometer only
  - **21** used both magnetometer and EMI
- Schonstedt flux-gate magnetometer most common, used in **35**
- EMI-based mapping used magnetometer or magnetometer and EMI instruments together in **45**
- Multiple instruments used at **30**

Of the 46 actions….

Module 1 – Recap/Conclusions

- What did you just learn?
  - Refresher on munitions response detection processes, operations, and technologies
  - What detection technologies are being selected for use on actual munitions response sites during munitions sweep, mapping, and reacquisition operations
- Next…how the detection technologies have performed during implementation on test sites and real sites

Preparation for Modules 2 & 3…

Now you have an idea of what is being used out there in the field based on the munitions operation type

It's good to know what technology is being used before we can evaluate how well they are performing.

39

Survey of Munitions Response Technologies

MODULE 2:

Interpreting Detection System Performance

No associated notes.

40

Module 2 Learning Objectives

- Provide an overview of detection technology survey results
  - Detection technology systems
    - 2 surveys
  - Methods used for analysis of detection technologies
  - Interpreting detection system performance

No associated notes.

41 **Source Data and Methodologies for Detection Technology Performance Analysis**

- Analysis relies on 2 sources of data
  - Standardized UXO test sites
  - Geophysical prove outs
- Instrument analysis from EM61 and Geonics G-858 performance

No associated notes.

42

Standardized Test Sites

- Description
  - Aberdeen Proving Ground (APG)
  - Yuma Proving Ground (YPG)
  - U.S. Army and SERDP/ESTCP joint effort
- Detailed information on the test sites is available from http://aec.army.mil/usaec/technology/uxo01.html

No associated notes.

43

Geophysical Prove Outs

- Survey examined GPOs for 22 munitions response actions at 18 sites from 1998 - 2004
- See Appendix C in Survey of Munitions Response Technologies

Additional information about Geophysical Prove Outs is available in the ITRC UXO team's technical and regulatory guidance document Geophysical Prove-Outs for Munitions Response Projects (UXO-3, 2004) and the associated Internet-based training.

ITRC guidance document from the UXO team are available to download at www.itrcweb.org under "Guidance Documents" and "Unexploded Ordnance" or directly at http://www.itrcweb.org/Documents/UXO-4.pdf

The associated Internet-based training is available at http://www.clu-in.org/conf/itrc/gpo_012505/

44

Methods for Analysis of Detection Technologies

- Probability of detection
- False alarm rate
- Target and sensor data
- Open field vs. seeded bed
- Depth considerations

No associated notes.

45

Probability of Detection Overview

- Pd = number of found/number of seeded items
- Probability of detecting a target will be a function of the following
  - Type of ordnance
  - Sensor type
  - Object depth and orientation
  - Sampling density
  - Crew capability
- http://www.prod.sandia.gov/cgi-bin/techlib/access-control.pl/1998/981769-1.pdf

Statistical Considerations in Designing Tests of Mine Detection Systems: I - Measures Related to the Probability of Detection, Sandia Report SAND98-1769/1 printed August 1998 available at http://www.prod.sandia.gov/cgi-bin/techlib/access-control.pl/1998/981769-1.pdf

46

False Alarm Rate Overview

- Background False Alarm Rate (FAR)
  - Number of non-ordnance targets picked divided by the area surveyed
  - See Appendix C; Table C-4 for results

No associated notes.

47

Detection Sensitivity Results

- Platforms
  - EM-61 & GEM-3
  - Geonics cesium-vapor G-858
- Open field vs. seeded bed
  - In tightly controlled environments, the EMI technologies were able to detect most seeded targets to 11x depth

No associated notes.

48

Common Causes of Missed Targets

- Target locations are unknown and real-world challenges, such as changes in topography, influence technology performance
- Common causes of missed targets include
  - Masking from nearby objects that emit stronger signals
  - Location inaccuracy in excess of the 0.5m requirement to be credited with a detection
  - Targets at a depth that exhibit low amplitude signals

No associated notes.

49

Detectability versus Depth by Ordnance Target – Small Ordnance

- Small ordnance – 20 mm projectiles
  - Most all technologies had difficulty detecting 20 mm projectiles
  - Targets are shallow
  - Field procedures and target selection methodology are not necessarily suitable for 20 mm

No associated notes.

50

Detectability versus Depth by Ordnance Target – Medium Ordnance

- Medium ordnance – 60 mm mortars
  - 100% of detection depth of approximately 0.5 meter approaches but does not reach the 11x rule of thumb for the better performing systems which include the EM-61 and GEM-based instruments

No associated notes.

51

Detectability versus Depth by Ordnance Target – Large Ordnance

- Large ordnance – 155mm
  - Detected up to and beyond the 11x rule of thumb
  - Deepest 100% detections were achieved using magnetometer-based systems

No associated notes.

52

Data Collection and Analysis Procedures Matter

- In both the open field and controlled test sites the same sensors can show significantly different results
- In situations where the same equipment was used, different Pds and FARs were recorded

No associated notes.

53

Differences in Performance

- Differences in theoretical and observed performance can be an indicator of many things such as
  - A single test is not always a good indicator of overall performance
  - Initial data quality objectives may be too restrictive
  - Site geology may limit detectability
  - Crew capability
- Quality checks
  - Developed to meet the remedial objectives of the project
  - Should be performed to ensure that the technologies selected are appropriate for the site

No associated notes.

54

Digital Geophysical Mapping (DGM) vs Mag & Flag

- Mag & Flag or EMI & Flag achieved a much lower maximum probability of detection than DGM
- Mag & Flag also produced much higher false alarm rates

No associated notes.

55

Digital Geophysical Mapping (DGM) vs Mag & Flag – Other Findings

- Small items
  - DGM and Mag & Flag performed similarly in detection
  - Mag & Flag false alarm rates were higher
- Medium items
  - 100% detection depths for DGM & Mag & Flag were comparable
  - Deepest items were consistently located with DGM
- Large items
  - 100% detection depths were greater with DGM
  - Deepest items were detected with DGM

No associated notes.

56

Major Findings from Test Sites and Open Field GPOs

- ▶ Evaluate results
  - To help determine technology most applicable to your site
- ▶ Pick technology
  - Depending on
    - Site conditions
    - Project objectives
  - To help achieve project goals

Remember when reviewing these major findings that the idea is to evaluate the results to help determine which technology will be most applicable to your applicable site

Depending on site conditions and project objectives, you'll want to pick and apply the correct technology to help achieve project goals

57

Major Findings (continued)

- All instruments have trouble isolating single items when anomaly signatures overlap
- DGM achieved
  - Higher probability of detection (Pd) than mag and flag
  - Lower false alarm rates (FAR) than mag and flag
- 11x rule of thumb
  - Items are detectable to depths approximately 11x their diameter
  - Reasonable for currently available sensors

DGM achieved higher probability of detection (Pd) and lower false alarm rates (FAR) than mag and flag

Rule of thumb that items are detectable to depths approximately 11x their diameter is reasonable for currently available sensors

58

Major Findings (continued)

- System noise
  - Generally not the limiting factor in detectability of munitions
- All systems have trouble detecting smaller items
  - Smaller items are more likely to be missed at shallower depths than larger items

No associated notes.

59

Major Findings (continued)

- No clear "winner" between
  - Magnetometer
  - EMI
- Magnetometers generally have lower Pds on an ensemble of mixed targets than EM devices
- Pds are lower for smaller ordnance
- Magnetometers are better at detecting deeper medium and large ordnance
  - 100% detection depths for 60 mm and 105 mm are consistently greater for systems containing a magnetometer component

No associated notes.

60

Major Findings (continued)

- EM61 typically performs best for most ordnance items in geophysical prove-outs with mixed ordnance type
  - EM61 typically locates 90-100% of seed items buried for most ordnance types from 37 mm to 155 mm
- Sensor selection requires consideration of
  - Munitions types of interest
  - Response action objectives
- For complex, mixed-use sites
  - More than one sensor type may be necessary

No associated notes.

Major Findings (continued)

- Aggregate Pds against ensembles of target types and depths provide limited information to support decisions
- Differences in sensor capabilities to detect munitions varies by
  - Size
  - Depth
  - Local clutter environment
  - Other factors

No associated notes.

Major Findings – Conclusion

- Only magnetometers and EMI sensors have demonstrated robust performance detecting buried munitions
- Standard test site and GPO data demonstrate magnetometer and EMI detection capability
- Proposals to use alternative technologies on MR projects should be scrutinized carefully

No associated notes.

63

Closing Thoughts: Project Objectives & Performance

- Project objectives
  - Determined by the project team when the project work plan is developed
- Data is a critical component to support project objectives and decisions
  - Data collection that meets the needs of the project
  - Data processing procedures that provide a target map that meet project goals
  - Data analysis helps to reduce the amount of false alarms

No associated notes.

64

Closing Thoughts: Quality in the Real World

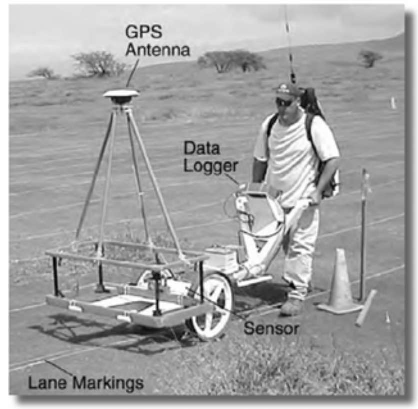
- Determining the quality objectives
  - Goes a long way in ensuring the success of the project
  - Defined as part of the development of project work plan
- Quality
  - Key factor in technology selection and performance
- Particular attention must be paid to the critical components of geophysics
  - Instrument selection
  - Survey design
  - Execution
  - Data reduction
  - Target-selection methodology
- ITRC UXO Team's document
  - Quality Consideration for Munitions Response (UXO-5, 2008)

Determining the quality objectives for a project will go a long way in ensuring the success of the project. Quality or success is defined as part of the development of project work plan

Quality is a key factor in technology selection and performance. Particular attention must be paid to the critical components of geophysics

Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) and associated support tools are available at http://www.epa.gov/fedfac/documents/qualityassurance.htm

Questions & Answers



No associated notes.

Survey of Munitions Response Technologies

MODULE 3:

Implementation Considerations:

Case Studies

No associated notes.

67

Module 3: Learning Objectives

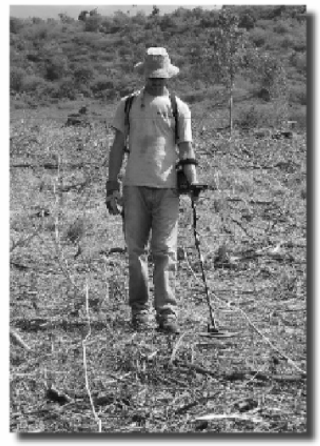
- Review case studies in Section 6.3
- Demonstrate how data from the document can be applied to real-world projects

No associated notes.

68

Case Studies

- Section 6.3 of *Survey of Munitions Response Technologies*
- Applies data from test site results to three scenarios
- Demonstrates how to use performance data from Chapter 5 to develop relevant metrics and select appropriate detection technologies



Note: The three scenarios are not actual sites. These are examples of how the information in the Technology document can be applied to project decision making in example scenarios and also how the test data can be extrapolated from the test objects to other types of anomalies.

69

Case Studies

- Three Scenarios
  1. Mortar Range
  2. Aerial Gunnery Range
  3. Artillery Range

[6.3] These are the three scenarios discussed in Section 6.3 of the Technology document. Again, no actual ranges were harmed during the preparation of this training.

70 **Case Studies: Scenario 1**
Mortar Range

- 60-mm and 81-mm mortars
- Single firing point
- Multiple targets in 100-acre central impact area
- Moderately dense MEC around targets
- Low-density MEC through rest of impact area

[6.3.1] Mortar Range Case Study background information.

71

Case Studies: Scenario 1 Mortar Range

- Surface-cleared of MEC
- No large trees or obstructions
- Surface clearance demonstrated no other types of munitions used
- Analysis of soil conditions: depth of penetration for 60-mm and 81-mm mortars does not exceed 0.5-meters

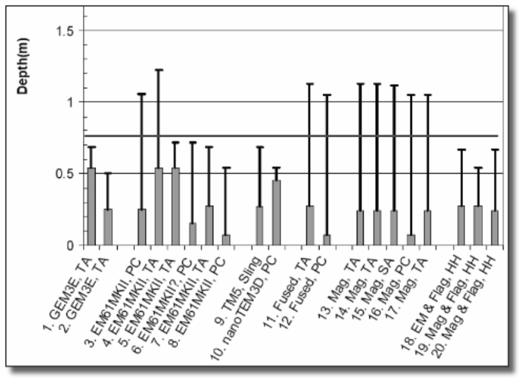
[6.3.1] Mortar Range Case Study background information continued.

72

Case Studies: Scenario 1 Mortar Range

Evaluate Figures 5-6 and 5-21

- Shows EMI in towed-array (two EM61 sensors and one GEM-3 sensor) had best detection performance
- Three demonstrators had 100% detection to depths of 0.5-meters
- Demonstrates that these systems have a high probability of detecting the MEC of interest on this site



[Section 6.3.1]

Figure 5-6 shows the detection rates for 60-mm mortars at various MEC depths. This figure identifies the sensors with the highest detection rates for the depth parameters relevant to this site. Note: The text reference to Figure 5-7 is an error and should reference Figure 5-6.

73

Case Studies: Scenario 1 Mortar Range

Further analysis of Figures 5-6 and 5-21 shows

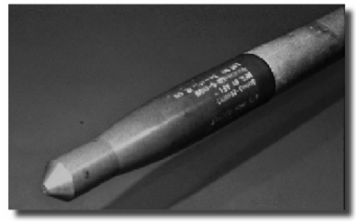
- Magnetometer systems (demonstrators 11 – 17) were able to detect 60-mm mortars deeper than 1-meter but were not consistent in performance
- 100% detection performance for magnetometer systems is 0.3-meters
- Therefore, mag systems are not ideal for this application

[6.3.1] Additional evaluation of Figure 5-21 provides this additional information on the suitability of magnetometer-based systems. This analysis shows that mag systems can detect mortars to deeper depths but their performance isn’t consistent. Based on this data, for this scenario (0.5-meter maximum depth), using a mag-based system can be expected to result in more undetected mortars.

74

Case Studies: Scenario 2
Aerial Gunnery Range

- Used for
  - 2.75-in. rockets
  - .50 cal., 20-mm, and 37-mm projectiles
  - .50 cal. have steel cores and no explosive hazard
- Several targets are heavily contaminated
- Dense contamination 50-meters around each target
- Moderate to low contamination across remainder of the site



[6.3.2] Background information for Scenario #2.

75

Case Studies: Scenario 2
Aerial Gunnery Range

- Site received surface clearance
- Free of vegetation except for isolated trees and shrubs
- Terrain is mostly flat with some rolling hills and one steep wash through center of one target
- Penetration statistics
  - 2.75-in. rockets
    - 2-meters
  - 37-mm projectiles
    - 0.5-meters
  - 20-mm projectiles
    - 0.25-meters

[6.3.2] Background information for Scenario #2 continued.

76

Case Studies: Scenario 2 Aerial Gunnery Range

- Review of **Tables 5-19 and 5-20** show that detection of small MEC (20-mm and 37-mm projectiles) varies greatly
- Medium sized MEC (2.75-in. rockets) are reliably detected by many systems
- Reliable detection of 20-mm and 37-mm projectiles should be carefully evaluated
- Results from test sites shows that smaller MEC are not reliably detected on sites with a mix of large and small MEC

[6.3.2] This conclusion is not supported by specific test data contained in the report. However, a general review of the test data for the standardized test sites shows that almost all demonstrators had noticeably lower detection performance for small MEC vs. medium and large MEC. However, almost all demonstrators detected at least some of the small MEC indicating that there is no inherent sensor limitation to detecting small MEC. The theory for these results is that the demonstrators could have done better if they had tailored their demonstration for the detection of small MEC.

77

Case Studies: Scenario 2 Aerial Gunnery Range

- All systems detected some 20-mm and 37-mm to deep depths showing detection is possible
- However, the signals from these MEC are small in amplitude and limited in spatial extent
- Sensor must pass very close to detect these MEC
- Therefore, appropriate field procedures are required to reliably detect small MEC

[6.3.2] Specialized field procedures can be implemented to increase the detection capability of small MEC. See the next slide for examples of “appropriate field procedures”.

78

Case Studies: Scenario 2 Aerial Gunnery Range

- Appropriate field procedures that may be appropriate
  - Decrease line spacing to solve the problem of the limited spatial extent for these small anomalies
  - Increase the number of sensors in a towed system or run more geophysical transects spaced closer together
  - Goal: acquire adequate number of sensor readings above background for the weakest anomaly of interest (the deepest MEC at the maximum offset)

[6.3.2] Examples of appropriate field procedures are focused on increasing data density by getting more data on transects spaced closer together. This maximizes the probability of detecting small MEC.

79

Case Studies: Scenario 2 Aerial Gunnery Range

- Appropriate field procedures (continued)
  - Lower sensor height to bring the sensor as close as possible to the MEC
  - However, this may also increase the sensor response to shallow clutter

[6.3.2] Lowering the sensor height to get closer to the small MEC may also help detect the small MEC. But there is a trade-off because placing the sensor closer to the ground surface will also increase the response to small metal clutter on and near the ground surface. Photo shows ground clutter removed from the surface of an MEC geophysical survey area.

80

Case Studies: Scenario 2
Aerial Gunnery Range

- Areas near trees and the deep wash are not accessible by the towed array and need an alternate solution
  - Man-carried sensors can be used in these specific areas
  - DQOs for the man-carried sensors should duplicate, as closely as possible, DQOs for the towed array sensor

[6.3.2] Difficult terrain may require the use of additional sensors.

81

Case Studies: Scenario 3 Artillery Range

- Impact target for 105-mm and 155-mm projectiles
- Single firing point
- Multiple targets in a downrange central impact area (CIA)
- 4 known high-density target areas
- Lower density MEC and scrap throughout the remainder of the CIA

[6.3.3] Background information for Scenario #3.

82

Case Studies: Scenario 3 Artillery Range

- CIA is level and grassy
- Good view of sky for GPS
- Geology is benign for geophysics
- Clearance of MEC to the depth of detection is required to support future land use
- Removal of all detectable MEC is desired

[6.3.3] Background information for Scenario #3 continued.

Case Studies: Scenario 3 Artillery Range

- Data on detection of large projectiles shows (Figure 5-6):
  - Magnetometer towed array DGM systems had the deepest detection
  - Maximum depth of detection for “mag and dig” processes is more shallow than for DGM (“mag and dig” = approximately 1-meter, DGM = 2-meters)
- Platform and sensor of choice for this application is magnetometer-towed array DGM

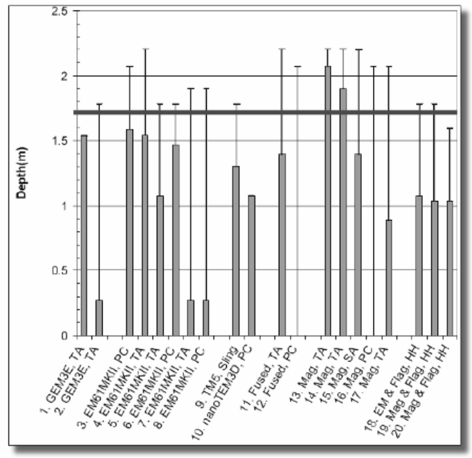


Figure 5-6 shows that magnetometer systems produced the deepest detection capability for large projectiles. Since removal of as many MEC as possible is desired and large projectiles can penetrate to deep depths, the maximum depth of detection offered by magnetometer towed array systems is desirable for this project.

[6.3.3]

84

Case Studies: Scenario 3 Artillery Range

- Note that several EM systems and the GEM towed array achieved 100% detection near or beyond 1.5-meters
- These systems may be appropriate on similar sites where
  - Maximum depth of detection is not the primary selection criteria
  - Penetration depth of the projectiles is limited due to bedrock

[6.3.3] If the scenario were slightly different (deepest detection was not required) then an EM system may also be appropriate.

85

Case Studies: Scenario 3 Artillery Range

- Other potential selection criteria may influence sensor and platform selection
- For example, detecting small bursters and fuzes from impacting UXO
- In this case, it is necessary to expand the sensor selection criteria to also detect small objects

[6.3.3] Other selection criteria may need to be implied. In this case, numerous bursters and fuzes from the impacting the 155-mm projectiles may need to be detected.

86

Case Studies: Scenario 3 Artillery Range

- Bursters and fuzes are not represented in the test site data
  - Therefore, comparably-sized MEC for which test site data is available can be used for comparison
  - For example, 20-mm or 37-mm projectiles
- EM towed array systems worked better on small objects
- A multiple-sensor approach may be needed in this case

[6.3.3] In this case, smaller MEC that were used in the demonstrations can be used as surrogates for the fuzes and bursters.

87

Training Summary

- Module 1: Detection Technologies
  - Overview and current state of the practice
- Module 2: Detection System Performance
  - What data is contained in the document
- Module 3: Case Studies
  - How to interpret and use the system performance data

No associated notes.

88

Thank You for Participating

- Links to additional resources at
  - http://www.clu-in.org/conf/itrc/uxost/resource.cfm
- 2nd Q&A session

Links to additional resources:
http://www.cluin.org/conf/itrc/uxost/resource.cfm

Your feedback is important – please fill out the form at:
http://www.cluin.org/conf/itrc/uxost/

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Be an official state member by appointing a POC (State Point of Contact) to the State Engagement Team

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects