Munitions Response Program Removal Technologies

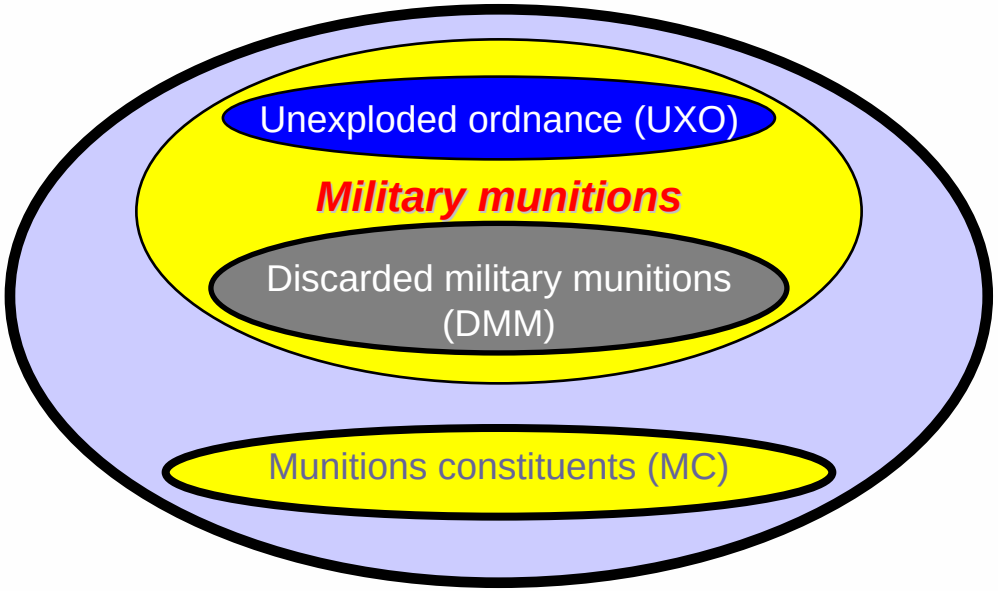
Naval Ordnance Safety & Security Activity (NOSSA)
Indian Head, MD

Presentation Overview

- Introduction
- Basic Explosives Safety Concepts
- Basic Anomaly Detection Concepts
- Manual Removal Technologies
- Mechanized Removal Technologies
- Remotely-Operated Removal Technologies
- Dredging Operation Removal Technologies
- Explosive Soil Removal Technologies
- Final Munitions and Explosives of Concern (MEC) Disposition
- Summary

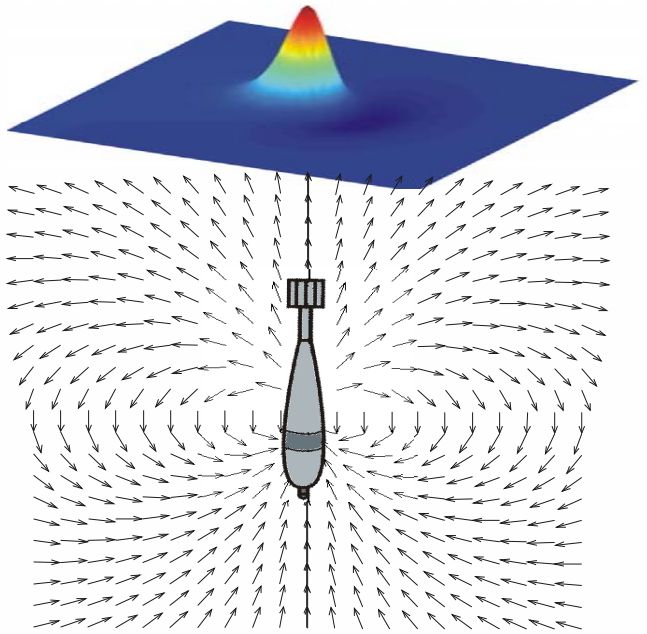
Definitions and Acronyms

- Munitions Response Program (MRP)
- Munitions and Explosives of Concern (MEC)
  - Discarded Military Munitions (DMM)
  - Unexploded Ordnance (UXO)
  - Munitions Constituents (MC) in high enough concentrations to pose an explosive hazard
- Net Explosive Weight (NEW)
- Explosives Safety Quantity Distance (ESQD) arcs and Exclusion Zones (EZs)



Definitions and Acronyms (cont.)

- Essential and non-essential personnel
- Open burning/open detonation (OB/OD)
- Hazardous fragment distance (HFD)
- Maximum fragment range (MFR)
- Maximum credible event (MCE)
- "Mag and flag"
- Electromagnetic induction (EMI)



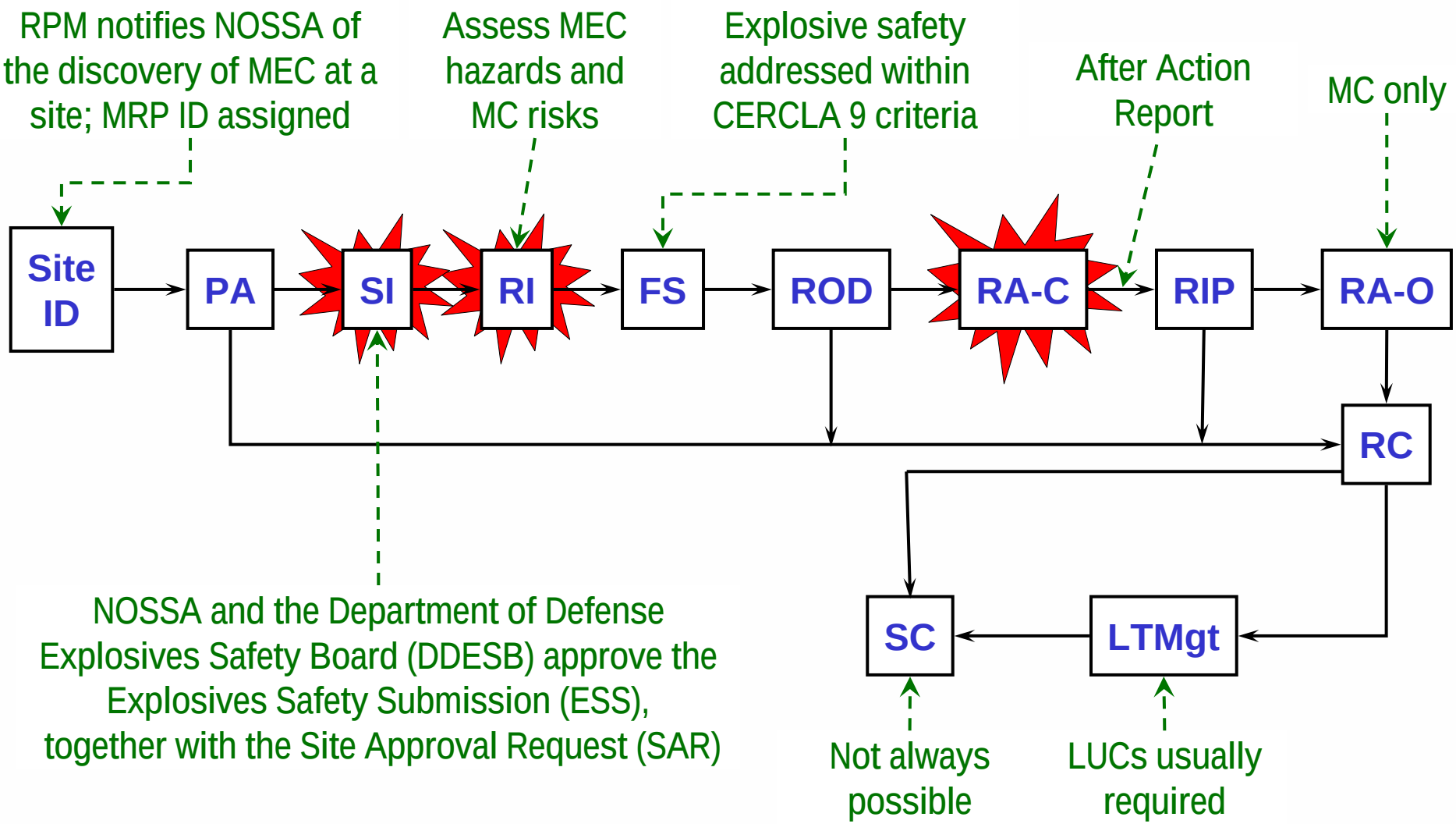
Topic Problem Statement

- When a munitions response is required, Remedial Project Managers (RPMs) need to be able to evaluate MEC removal technologies proposed by their contractors and regulators/ stakeholders
  - Which removal technologies can achieve the cleanup objective?
  - Which removal technologies are most cost effective?
  - Which removal technology is most readily implemented?
  - During project execution, which removal technologies present an acceptable hazard to essential and no hazard to non-essential personnel?

Topic Context

- Fall 2006 RITS – Munitions Response Program:
  - Inside the MRP
  - Explosives safety requirements
  - Naval Ordnance Safety & Security Activity (NOSSA)
  - Potential MRP project execution challenges
  - Help for the RPM
- Spring 2007 RITS – Characterization of Energetic Constituents on Ranges:
  - Introduction to energetic chemicals used by DoD
  - Overview of various types of DoD training ranges with emphasis on residues present
  - Residue deposition studies
  - Characterization research
  - Sample processing and sub-sampling issues
  - Laboratory determination

Topic Context (cont.)



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Rules to (Literally) Live By

- Expose the fewest number of persons to the smallest amount of explosives for the shortest period of time
- Minimize or reduce explosive hazards through:
  - Distance
    - Blast overpressure and fragment speed and density drop as distance from explosion increases
    - EZs protect non-essential personnel during cleanup operations
  - Barriers and/or engineering controls
    - Shields, barricades, berms, trenches, etc. to protect both essential and non-essential personnel during cleanup operations

Munitions with the Greatest Fragment Distance

- Munitions with the Greatest Fragment Distance (MGFD)
  - MGFD is the MEC about which we need to be most concerned
    - Selected by identifying all anticipated MEC and then looking up their respective maximum fragment range (MFR)
  - MGFD is basis for ESQD arcs and EZs both in terms of:
    - Fragments; and
    - Blast over pressure

MEC	NEW (lbs)	HFD* (ft)	MFR (ft)
20-mm projectile	0.3	200	558
40-mm projectile	0.2	200	1,095
3-in./50 projectile	0.2	200	1,595
5-in./38 projectile	7.25	308	1,925

*Hazardous fragment distance

Determining ESQD Arcs and EZs

Personnel	Intentional Detonation	Unintentional Detonation	
		Mechanized Operations	Manual Operations
Essential	K=328 or[1] maximum frag range (MFR)	K=24 + shield or barricade	K=40[2]
Non-essential	K=328 or[1] MFR	K=328 or[1] MFR	K=40 or[1] HFD[3]

- Formula for determining blast overpressure separation distances for Class/Division (C/D) 1.1 material is $D=KW^{1/3}$ where:
  - D is the separation distance in feet;
  - K is a factor that varies depending on the hazard assumed or permitted; and
  - W is the NEW of the MGFD expressed in lbs of TNT equivalent

Notes:
[1] Choose longest distance
[2] Minimum team separation distance
[3] The same as inhabited building distance

Source: OP 5, Change 5

Application of ESQD Arcs and EZs

- Selected MGFD is the 5-in/38 projectile

Personnel	Intentional Detonation	Unintentional Detonation	
		Mechanized Operations	Manual Operations
Essential	K=328 of 629 ft or[1] MFR of 1,925 ft	K=24 of 47 ft + 3.84-in Plexiglas®	K=40[2] of 77 ft
Non-essential	K=328 of 629 ft or[1] MFR of 1,925 ft	K=328 of 629 ft or[1] MFR of 1,925 ft	K=40 of 77 ft or[1] HFD[3] of 308 ft

Notes:
[1] Choose longest distance
[2] Minimum team separation distance
[3] The same as inhabited building distance

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Detecting MEC Using "Mag and Flag"

- "Mag and Flag" operations locate subsurface anomalies by sensing changes made by ferrous objects to the earth's magnetic field
  - Step 1: Remove excess vegetation
  - Step 2: Unexploded ordnance (UXO) technician surveys each lane of a grid using a magnetometer or gradiometer
  - Step 3: Based on audio signal strength and pitch, UXO technician selects anomalies to be dug and marks selection with either a pin flag or a global positioning system (GPS) location

"Mag and Flag" Operations

Detecting MEC using Electromagnetic Induction (EMI)

- EMI instruments locate subsurface anomalies by first inducing a magnetic field in metallic objects and then recording the return signal
  - Step 1: Remove excess vegetation
  - Step 2: Geophysical technicians transport survey instruments over a pre-identified grid transect
  - Step 3: Anomalies recorded electronically

EMI Survey

  - Step 4: Geophysicist analyzes the data and selects anomalies to be dug

Detecting MEC Underwater

- No standardized technical approach available
  - Hydrographic/bathymetric, side-scan sonar, diver “mag and flag” and EMI surveys are useful, but yield incomplete results
  - Detecting medium and small items often not possible
  - Obtaining precise and accurate positioning of bottom-located items is problematic
  - Under development are remotely operated vehicles, autonomous underwater vehicles, and more

ESTCP-Sponsored Demonstration of AETC’s Underwater Multiple Towed Array

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When to Manually Remove MEC

- Manual removal is the preferred approach when:
  - MEC are judged to be relatively close to the surface
  - The soil is easy to dig and common hand tools can be used to reach MEC
  - There is low metallic clutter so MEC are detected as discrete anomalies
- RPM must compare costs and hazards against those of mechanized MEC processing operations

40-mm Anti-Aircraft Projectile

When to Manually Remove MEC (cont.)

- Examples of sites where low metallic clutter can be expected:
  - Areas adjacent to flight lines
  - Weapons storage areas
  - Artillery and mortar ranges (except targets)
  - Bombing and gunnery ranges (except targets)

Surface Metallic Clutter on a Former Navy Bombing Range Target Area

How to Manually Remove MEC

- For “mag and flag” operations, UXO technician selects the pin flag or GPS position and reacquires the anomaly using a handheld geophysical instrument
- For EMI operations, UXO technician selects the GPS position and reacquires the anomaly using a handheld geophysical instrument
- For both operations, anomaly accessed using hand tools—e.g., shovels, trowels

Manual MEC Removal Operations

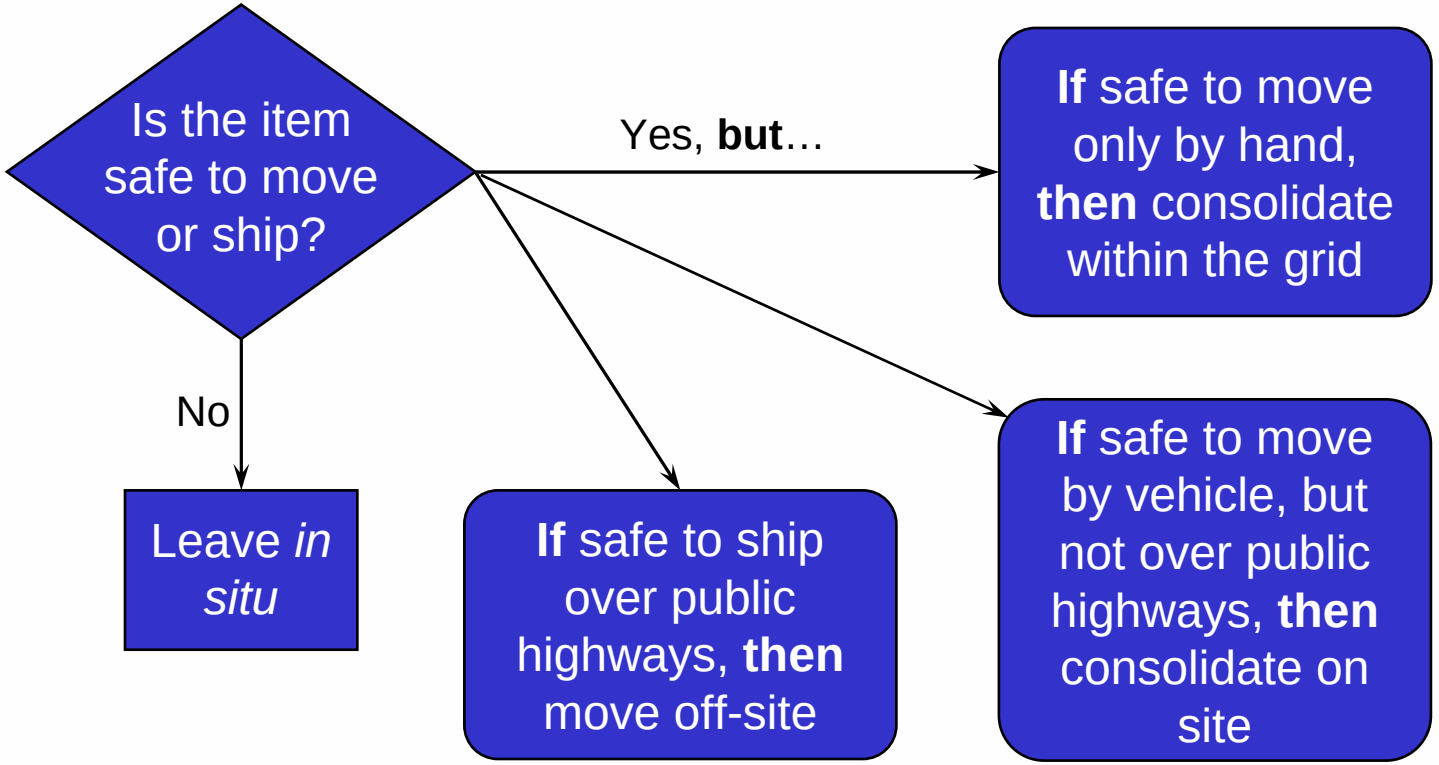
How to Manually Remove MEC (cont.)

- Manual MEC removal technologies apply controlled, low-energy forces to soils around—but none directly to—MEC
  - Dig vertically beside the anomaly, then dig horizontally until MEC is encountered
- Exception: during manual removal operations, heavy equipment may
  - Dig beside the anomaly
  - Dig incrementally over the anomaly until within 1 ft of it
  - Assist in lifting large items

Manual Removal Operations

How to Manually Remove MEC (cont.)

- UXO teams identify MEC item, record particulars (including photograph), and assess its condition



Managing Recovered MEC Items

- Options for managing recovered MEC items inspected and determined to be:
  - Unsafe to move
    - Blow in place (BIP) by UXO teams or supporting Explosive Ordnance Disposal (EOD) unit
  - Safe to move, but not safe to ship
    - Held for on-site open burning/open detonation (OB/OD) by UXO teams or supporting EOD unit
  - Safe to ship
    - Transported by UXO contractor or EOD to permitted (or interim status) off-site treatment facility

Transporting Explosives

- *In situ* treatment of recovered MEC is preferred option
  - Transporting exposes others to hazard
- If off-site transportation is necessary, obtain:
  - Interim hazard classification available from NOSSA (N82)
  - Safe-to-ship certification
    - For UXO, obtain certificate from EOD
    - For DMM and MC, obtain certificate from UXO contractor
  - Certificate of equivalency obtained from the Naval Packaging, Handling, Storage and Transportation Center

Explosives Transporting Vehicle

Personnel Protection During Manual MEC Removal

- Essential personnel must be protected from blast overpressure
  - ≥K=40 distance for MEC having largest NEW (referred to as "team separation" distance)
  - Under most circumstances essential personnel are not afforded protection from hazardous fragments
- Non-essential personnel must be protected by the greater of:
  - ≥K=40 distance for MEC having largest NEW; or
  - Hazardous fragment distance (HFD)

5-in. Projectile

Personnel Protection During Manual MEC Removal (cont.)

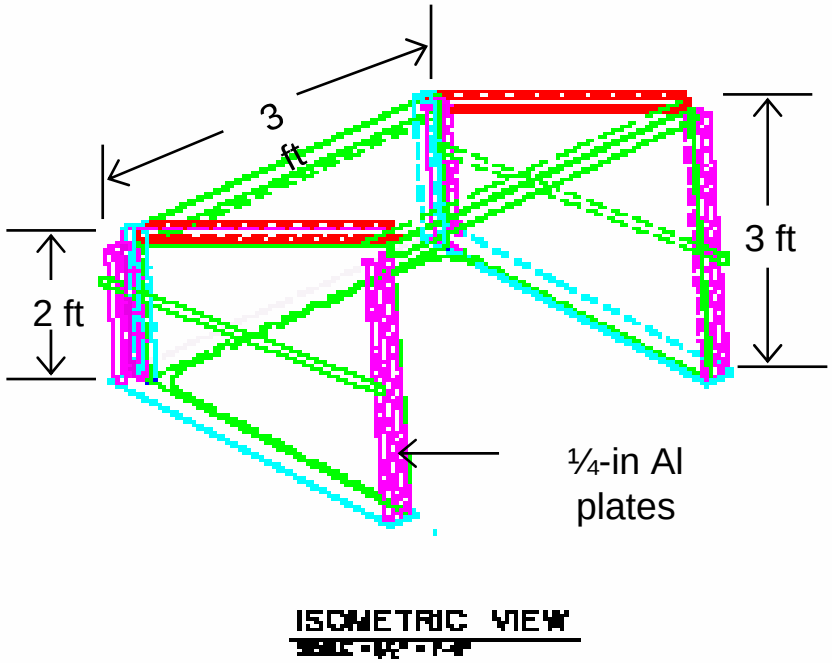
Essential Personnel K=40 Distance	
20-mm M56A4 projectile	13 ft
40-mm Mk 2 projectile	24 ft
3-in./50 Mk 29 projectile	21 ft
5-in./38 Mk 35 projectile	77 ft

Non-essential Personnel K=40 or[1] Hazardous Fragment Distances	
20-mm M56A4 projectile	13 ft or 61 ft
40-mm Mk 2 projectile	24 ft or 131 ft
3-in./50 Mk 29 projectile	21 ft or 98 ft
5-in./38 Mk 35 projectile	77 ft or 308 ft

[1] Choose longest distance

Personnel Protection During Manual MEC Removal (cont.)

- Army Corps of Engineers' miniature open-front barricade (MOFB)
  - Portable shield made of aluminum
    - Basic MOFB weighs 100 lbs
  - Basic MOFB can protect against unintentional detonation of up to an 81-mm mortar
    - Aluminum plates can be added for greater protection



Miniature Open-Front Barricade, a.k.a. "Bud Light".
Drawing courtesy of U.S. Army Engineering Support Center, Huntsville

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When to Use Mechanized MEC Removal Technologies

- Mechanized removal is the preferred approach when:
  - MEC are found in soil too deep or too hard for hand excavation;
  - MEC occur in clusters or masses; or
  - High density metallic anomalous objects makes detecting individual anomalies challenging
- RPM must compare costs and hazards against those of manual MEC processing operations

Excavator and Screening Plant

When to Use Mechanized MEC Removal Technologies (cont.)

- Examples of sites with high metallic clutter:
  - Bombing and gunnery range targets
  - Burial pits
  - Dredge spoil pipeline outfalls
  - Landfills and scrap yards on weapon stations, ranges, test facilities, etc.
  - OB/OD ranges

Typical Landfill Surprise

When to Use Mechanized MEC Removal Technologies (cont.)

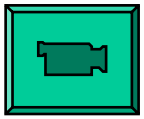
- Mechanized technologies work best with:
  - <20% slope
  - Minimal vegetation
  - Areas not environmentally sensitive
  - Non-cohesive soils

Mechanized MEC Operations

De-watered Dredge Spoil
Sediments Rejected by Screen

Types of Mechanized MEC Removal Technologies

- Mechanized MEC processing operations include the following categories of equipment:
  - Earth movers/scrapers
  - Front-end loaders/excavators (note Slide 21 exceptions)
  - Armored bulldozers
  - Vegetation removal equipment (except hand saws, machetes, chainsaws, and string trimmers/ brush cutters)



Video clip courtesy of Timberline Environmental Services

The "Spyder"
Photo courtesy of Kemp West, Inc.

Types of Mechanized MEC Removal Technologies (cont.)

- Power screening equipment is also considered a mechanized MEC process
  - Soil placed in grizzly or hopper, then screened
    - Screen sizes are reduced as material progresses through plant
  - Last screen must preclude smallest MEC from getting through
    - e.g., ¾-in. screen required if 20-mm projectile is smallest MEC item of concern

Trommel Screen

Protection During Mechanized MEC Removal

- Mechanized MEC processing operations apply indiscriminate, high-energy forces to soils and MEC alike
- Essential personnel must be protected
  - ≥K=24 distance for MEC having largest NEW *and*
  - Shields or barricades to protect workers against hazardous fragments
- Non-essential personnel must also be protected by the greater of
  - MFR or
  - ≥K=328 distance for MEC having largest NEW

Mechanized MEC Operations

Protection During Mechanized MEC Removal (cont.)

Essential Personnel K=24 Distance and Plexiglas® Shielding Thicknesses	
20-mm M56A4 projectile	8 ft and 1.13 in
40-mm Mk 2 projectile	14 ft and 2.08 in
3-in./50 Mk 29 projectile	13 ft and 2.96 in
5-in./38 Mk 35 projectile	47 ft and 3.84 in

Non-essential Personnel K=328 Distance or[1] Maximum Fragment Range	
20-mm M56A4 projectile	107 ft or 558 ft
40-mm Mk 2 projectile	199 ft or 1,095 ft
3-in./50 Mk 29 projectile	171 ft or 1,595 ft
5-in./38 Mk 35 projectile	629 ft or 1,925 ft

[1] Choose longest distance

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Remotely-Operated Removal Technologies

- Used where K=24 protection for essential personnel cannot be achieved
  - Example: excavating for a 5-in./38 caliber Mk 35 projectile and the excavator arm is shorter than 47 ft

Advanced Mobility Research and Development System with Autonomous Sensor Platform
Photo courtesy of the U.S. Air Force Research Laboratory

Tele-operated Caterpillar 325L Excavator and Caterpillar D8 Bulldozer
Photo courtesy of the U.S. Air Force Research Laboratory

Remotely-Operated Removal Technologies (cont.)

- Remotely-operated equipment requires no shields for equipment operator and/or observer
- Remotely-controlled closed-circuit television (CCTV)
  - Must be used when K=24 distance puts UXO observers too far away to properly observe operations

Remotely-Operated Equipment Control Room

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Common Dredging Technologies

- Mechanical dredging
  - Scoops or grabs material from the bottom
    - Equipment used includes bucket, clamshell, and backhoe
  - Places material into barges or scows for shipment to placement site

Mechanical Dredge – Conventional Clam
Photo courtesy of Bean Dredging

Common Dredging Technologies (cont.)

- Hydraulic dredging
  - A cutter-head cuts bottom and pumps force entrained material through pipelines
  - Entrained slurry material is either pumped directly into a hopper for later placement on land placement site or pumped directly to a dredge spoils lay-down area

Hydraulic Dredge – Conventional Cutter-head
Photo courtesy of Ellicott Dredge

Both Dredging Technologies Can Bring Up Submerged MEC

- MEC recovered from around piers is usually DMM
- Sufficient forces are present in dredging equipment to cause MEC to detonate
- If MEC fails to detonate, it can be inadvertently transported to dredge spoils lay-down area

Mechanical Dredging Operation
Photo courtesy of U.S. Army Corps of Engineers

Hazards Posed by MEC in Dredged Material

- MEC have been dredged from underwater sites—some suspected, some not suspected to contain MEC:
  - Buckroe Beach, VA
  - Eagle River Flats, AK
  - NWS Earle Pier Complex, NJ
  - Philadelphia Naval Yard, PA
  - Sandbridge Beach, VA
  - San Diego Channel, CA
  - Sea Bright Beach, NJ
  - Toussaint River, OH

Dredging Cutterhead
Photo courtesy of U.S. Army Corps of Engineers

5-in. Projectiles Recovered from Underwater

Dredge Material Must be Raked or Screened to Remove MEC

- Best accomplished after de-watering…

Dredge Spoils Screening Operation

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Explosive Soil

- Soil containing MC in high enough concentrations to pose an explosive hazard are considered “explosive soil”
  - Must be managed as C/D 1.1 (explosives with a mass explosion hazard)
  - “Explosive soil” most often encountered when remediating:
    - Manufacturing plant settling ponds or lagoons
    - Demilitarization facilities
    - Open burning/open detonation units
- Soil containing MC in lower concentrations is managed as chemically contaminated soil

Explosive Soil Removal Technologies

- Great care must be taken in excavating “explosive soil”
  - Mechanized removal operations may require that "explosive soil" be desensitized—i.e., soil augmented with water or mineral oil
- “Explosive soil” must be containerized for shipment, after first obtaining:
  - Interim hazard classification; and
  - Certificate of equivalency

UXO Technicians Performing Field Analysis of Contaminated Soil

Explosive Soil Safety Considerations

- ESQD arcs required for “explosive soil” are calculated based on maximum credible event (MCE)
  - Weight of mix times concentration of explosives (for example, 1,000 lb of soil containing 15 percent TNT has an MCE of 150 lb)
- Minimum separation distance for non-essential personnel shall be the greater of:
  - Inhabited building distance for overpressure; or
  - Soil ejecta radii
- If stored, C/D 1.1 explosive rules apply

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Final MEC Disposition

- Recovered MEC must be properly treated by the safest means available
  - Preferred option is to treat recovered MEC *in situ*
    - Open burning (OB) or open detonation (OD)
    - Laser neutralization

OB of Missile Motor

OD of Bombs

Final MEC Disposition (cont.)

- *Ex situ* options
  - Consolidate and treat on-site, or ship and treat off-site using
    - Thermal neutralization, including OB/OD processes
    - Chemical neutralization
  - Treat on-site using Contained Detonation Chamber (CDC)

T-10 CDC Chamber
Photo and video clip courtesy of DeMil International

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Summary

- The take-home messages:
  - Explosives safety is the major consideration when selecting cleanup technology
  - Both essential and non-essential personnel must be protected from intentional and unintentional detonations of MEC, but non-essential personnel are afforded greater protection
  - Mechanized MEC removal technologies apply forces sufficient to cause the MEC to detonate

MEC Screening Operations

Conclusions

- There are a wide variety of options out there to remove MEC and “explosive soil”
  - Some are simple, others are complex
  - Some are cheap, others are costly
- RPM must weigh the various removal technology costs against their hazards and implementability
  - Remember: explosives safety considerations trump all others
- There is a broad support network out there to assist the RPM

Civil Engineer Corps Officer School – Munitions Response Site Management Course Topics

- MEC Basics
- Regulations, Policies, and Guidance
- Program Overview/Execution
- Roles and Responsibilities
- Explosives Safety Basics
- Detecting MEC
- Preliminary Assessment/Site Inspection (with exercise)
- Site Prioritization (with exercise)
- Hazard Communication
- Remedial Investigation
- Feasibility Study and Risk/ Hazard Assessment (with exercise)
- Remedy
- Record of Decision and Beyond
- Look Ahead

Documents

- NAVSEA OP 5, Ammunition and Explosives Safety Ashore, 15 January 2001 (Chg 5, 15 Oct 06): https://intranet.nossa.navsea.navy.mil
- NOSSAINST 8020.15A, Explosives Safety Review, Oversight, and Verification of Munitions Response, 2 Feb 07: https://intranet.nossa.navsea.navy.mil
- Navy Environmental Restoration Program (NERP) Manual, August 2006: http://enviro.nfesc.navy.mil/erb/erb_a/restoration/NERP
- NAVFAC Business Management System (BMS) forms for the Munitions Response Program are on the NAVFAC portal: https://portal.navfac.navy.mil/portal
- Survey of Munitions Response Technologies, June 2006: http://www.itrcweb.org/Documents/UXO-4.pdf

Documents (cont.)

- Environmental Security Technology Certification Program (ESTCP) Military Munitions recovery and disposal completed and verified project reports
  - ☑ Laser Neutralization of Hazardous UXO (MM-9909)
  - – Low-Cost Hot Gas Decontamination of Explosives-Contaminated Firing Range Scrap (MM-0032)
  - – Low-Order, Underwater Detonation Study (MM-0104)
  - – Non-Thermal On-Site Decontamination and Destruction of Practice Bombs (MM-0211)
  - ☑ Dredging Equipment Modifications for Detection and Removal of Ordnance (MM-0321)
  - – Decontamination of Test Range Metal Debris Using a Transportable Flashing Furnace (MM-0412)
- Download at http://www.estcp.org/Technology/MM-Recovery-Disposal.cfm

Web Sites

- NOSSA secure Web site https://intranet.nossa.navsea.navy.mil
- MR Work Group Web site https://portal.navfac.navy.mil/go/erb or at the MR Portal http://www.ert2.org
- ITRC UXO Team documents http://www.itrcweb.org/gd_UXO.asp
- To sign up for next Munitions Response Site Management course go to https://www.cecos.navy.mil/coursedetail.cfm?courseid=45
  - 8-10 Jan 08 – Norfolk, VA
  - 22-24 Apr 08 – Honolulu, HI