Mine Countermeasures 101

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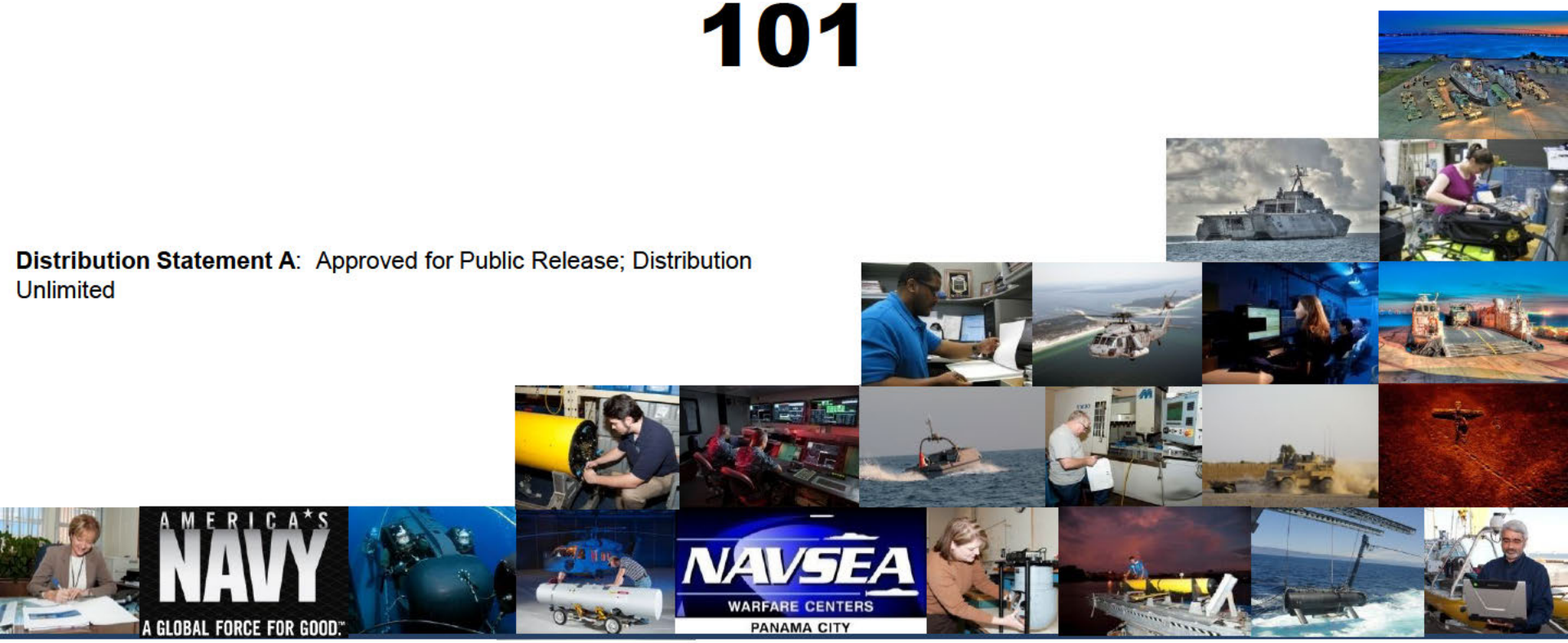


Technical Center of Excellence for Littoral Warfare and Coastal Defense

Outline

- Mine Countermeasures (MCM) Operational Planning
  - Basic Planning Principals
  - Scheduling
- MCM Planning Theory
  - Performance Parameters

MCM OPERATIONAL PLANNING
BASIC PLANNING PRINCIPALS

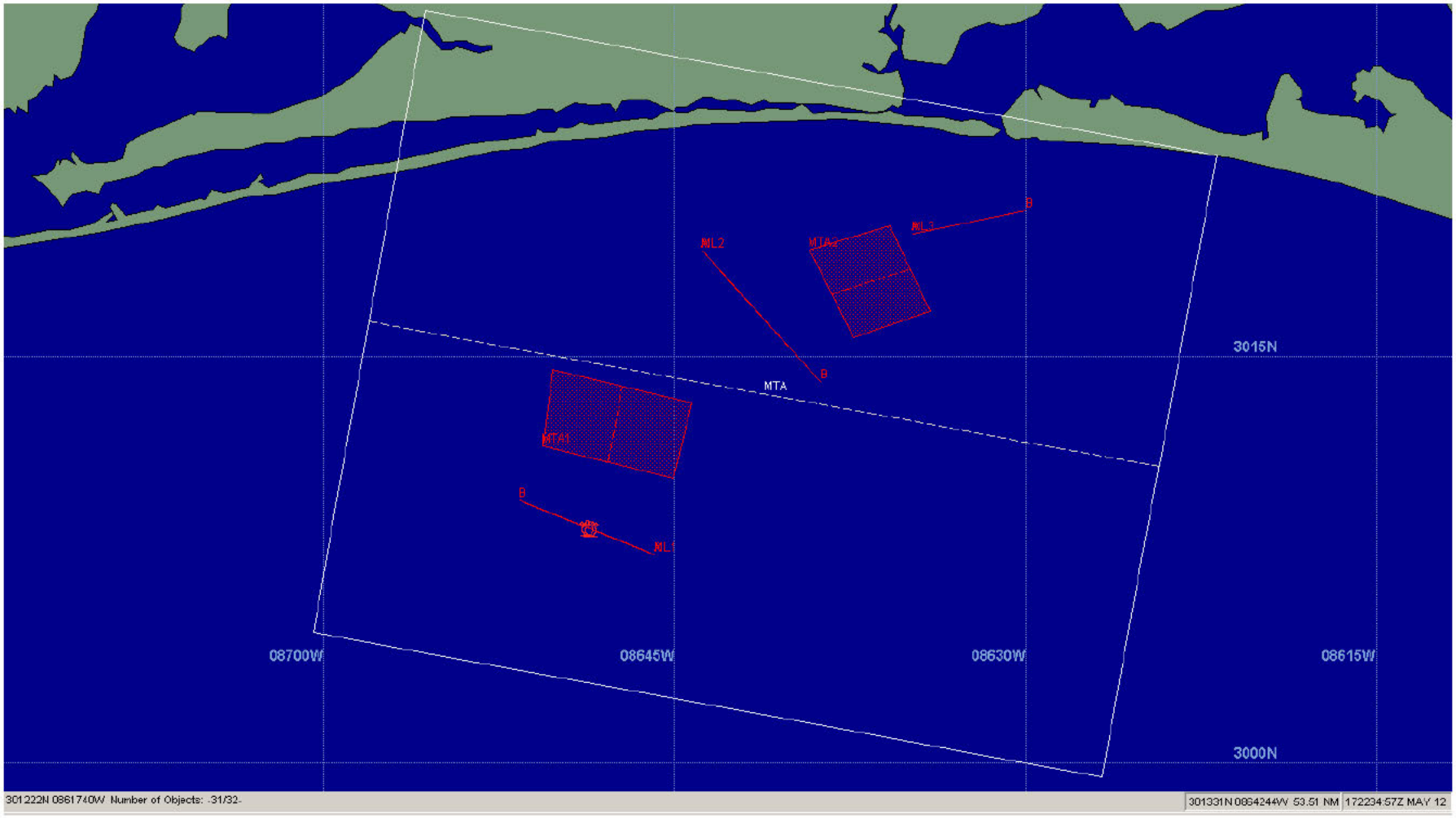
Basic Planning

- The purpose of this brief is to describe planning of an MCM mission
- MCM Planning has four major elements to consider
  - Area
  - Mine Threat Types and Placement
  - Environment as it Affects Mines and MCM Equipment
  - Available Platforms, Equipment, and Equipment Configurations

Mined Area

- Mine Threat Area (MTA)
  - Large area thought to be mined
  - Shape and size based on Military Objective of Enemy
    - Stop shipping in the channel, prevent landing on beach
- Minefields – Enemy Courses of Action (ECOA)
  - Located within the MTA
  - Mines are located in order to meet Enemy's Military Objective
  - Mines can be laid in mine lines or randomly placed within a box
  - Mines placed in water depths and locations to best cause damage to ships
    - MOE is threat to traffic
  - Planner should consider most likely and most dangerous ECOAs

MTA and Mine Lines



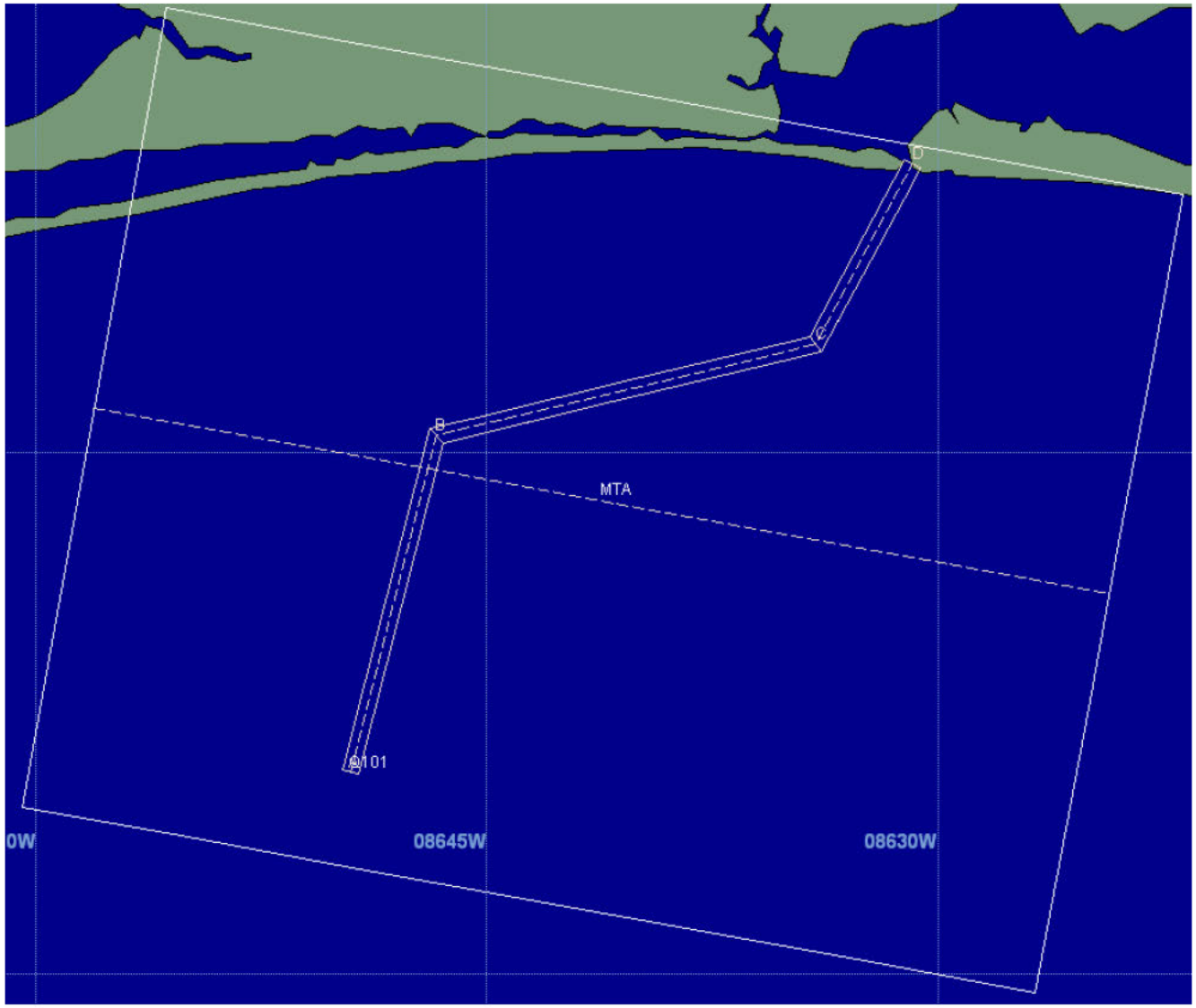
Commander's Planning Task

- The MCM Commander (MCMC) must address the following items when developing a plan
  - Desired MCM Objective(s)
  - Geographic Areas of importance
  - Mine Threat
  - Measures of Effectiveness
  - Risk
  - Vulnerability & Susceptibility of potential transitors
  - Critical Timing of Events

Area Requiring MCM

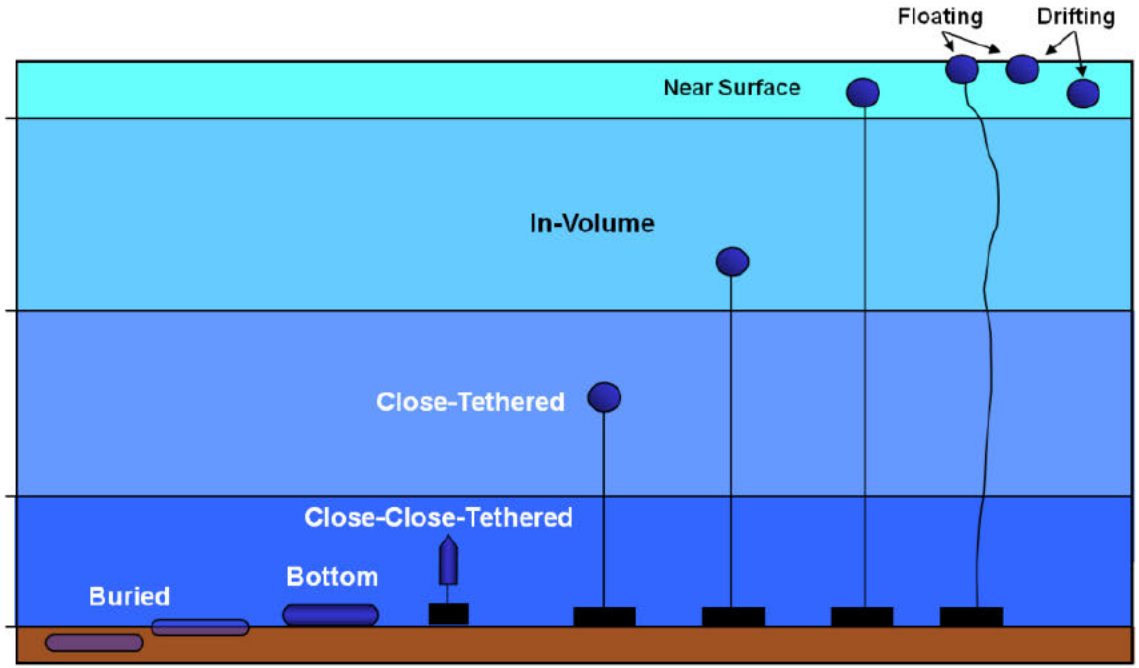
- Shape and size are based on COA
  - Allow ships to transit in/out of port, land craft on beach, remove all mines
- Typical shapes and sizes
  - Q-route (channel)
  - Patrol Area/Transport Areas
    - Square/rectangular shape used for ships to loiter
  - Amphibious Operational Area (AOA)
    - Usually combination of routes and patrol areas leading to beach
  - Mine Danger Areas (MDA)
    - Circle identified around a known mine
- Areas requiring MCM Effort
  - Based on COA
    - Remove all mines – apply MCM in all areas where mines can be planted
    - Ships to transit – apply MCM only in areas where mines are threat to traffic ship

Route



Threat Position in Water Column

- Four positions for mines in water column
  - Bottom – Mines laid on sea floor
  - Close-Tethered – Mines tethered close to the sea floor
  - Moored – Mines tethered at a depth in which the sea floor does not interfere with sonar
  - Floating



Threat Positioning

- Bottom Mines
  - Easy to deploy
  - Blend in with bottom sediment and clutter
  - Potential for burial in certain sediments
  - Reverberation from bottom causes difficulty with sonar
- Moored Mines
  - Difficult to deploy due to mooring cable and anchor
  - More likely to sink or migrate
  - Less reverberation from surface and/or bottom
  - Can cause collision or entanglement with equipment towed at or below mooring depth
- Close-Tethered Mines
  - Difficult to deploy due to attempting correct mooring length
  - Reverberation from bottom causes difficulty with sonar
- Floating Mines
  - Easy to deploy

Mine Types of Detonation

- Type of Mine Detonations
  - Contact – Mines detonated by contact with ship
  - Influence – Mines detonated based on acoustic, magnetic, and/or pressure signatures

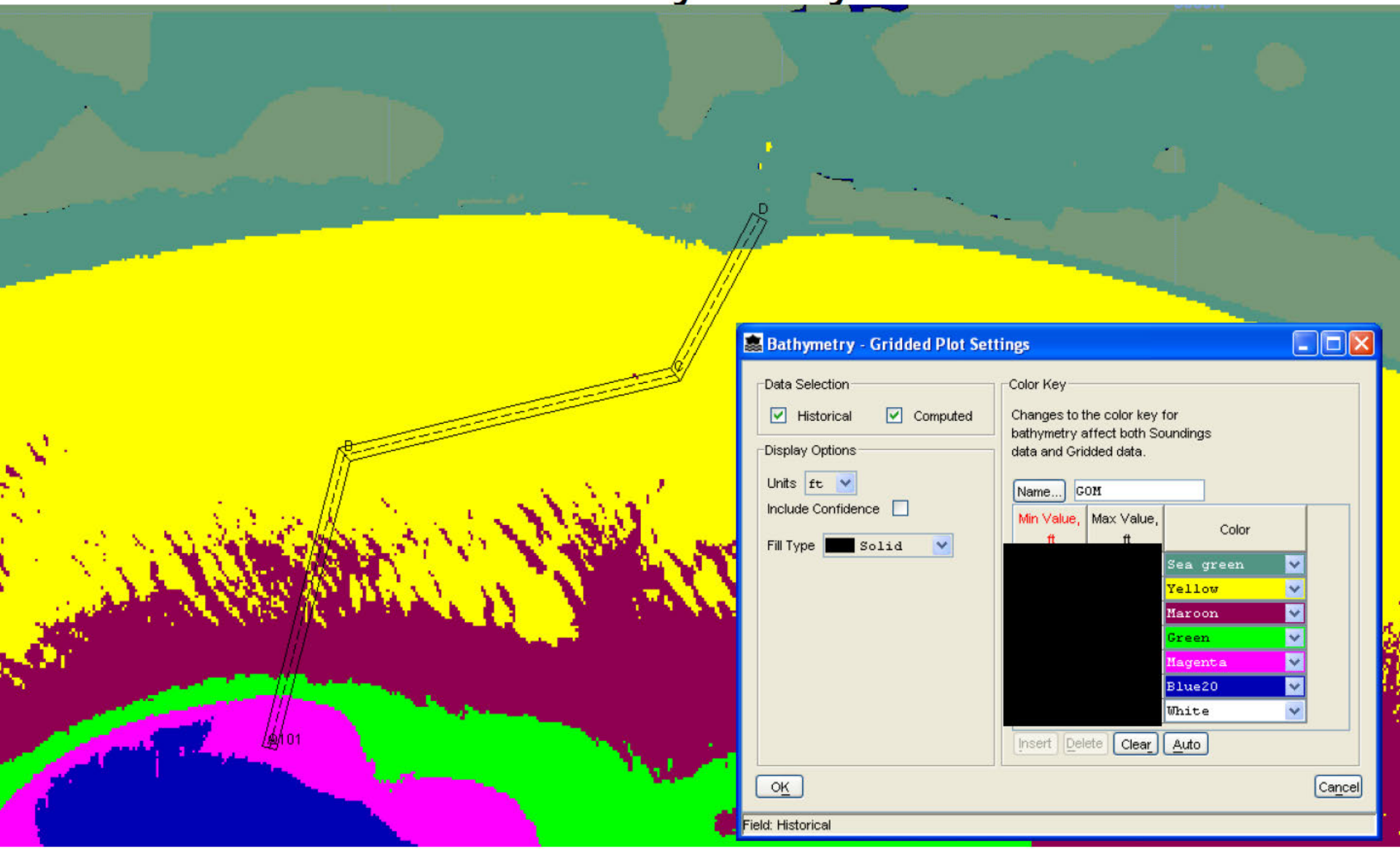
Type	Contact	Influence
Bottom		
Moored		
Near Surface		
Close-Tethered		

Areas in which Mine is a Threat

- Mine Placement
  - Bottom Mines are defined by depth limits
  - Moored and close-tethered mines are defined by anchor depth limits (cable length)
    - Mooring depth must also be considered
  - Floating mines have no depth limitations

Mine	Anchor Depth Min (ft)	Anchor Depth Max (ft)	Mooring Depth Min (ft)	Mooring Depth Max (ft)
Bottom				
Moored 1				
Moored 2				
Near Surface				

Bathymetry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C
B
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101
Bathymetry - Gridded Plot Settings
Data Selection
Historical
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ft
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Changes to the color key for bathymetry affect both Soundings data and Gridded data.
Name...
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Min Value, ft
Max Value, ft
Color
Sea green
Yellow
Maroon
Green
Magenta
Blue20
White
Insert
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Clear
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OK
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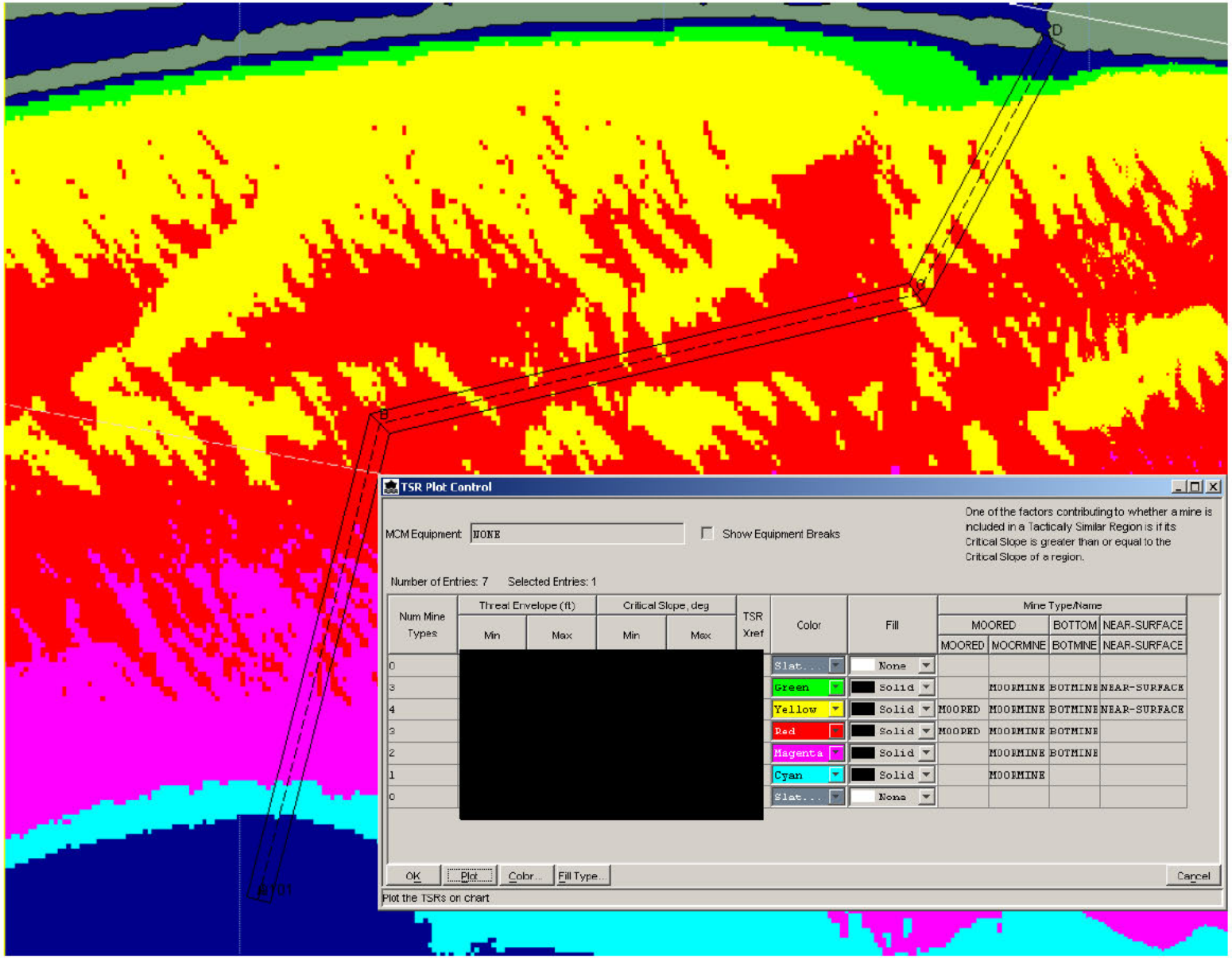
Mine Factor Analysis



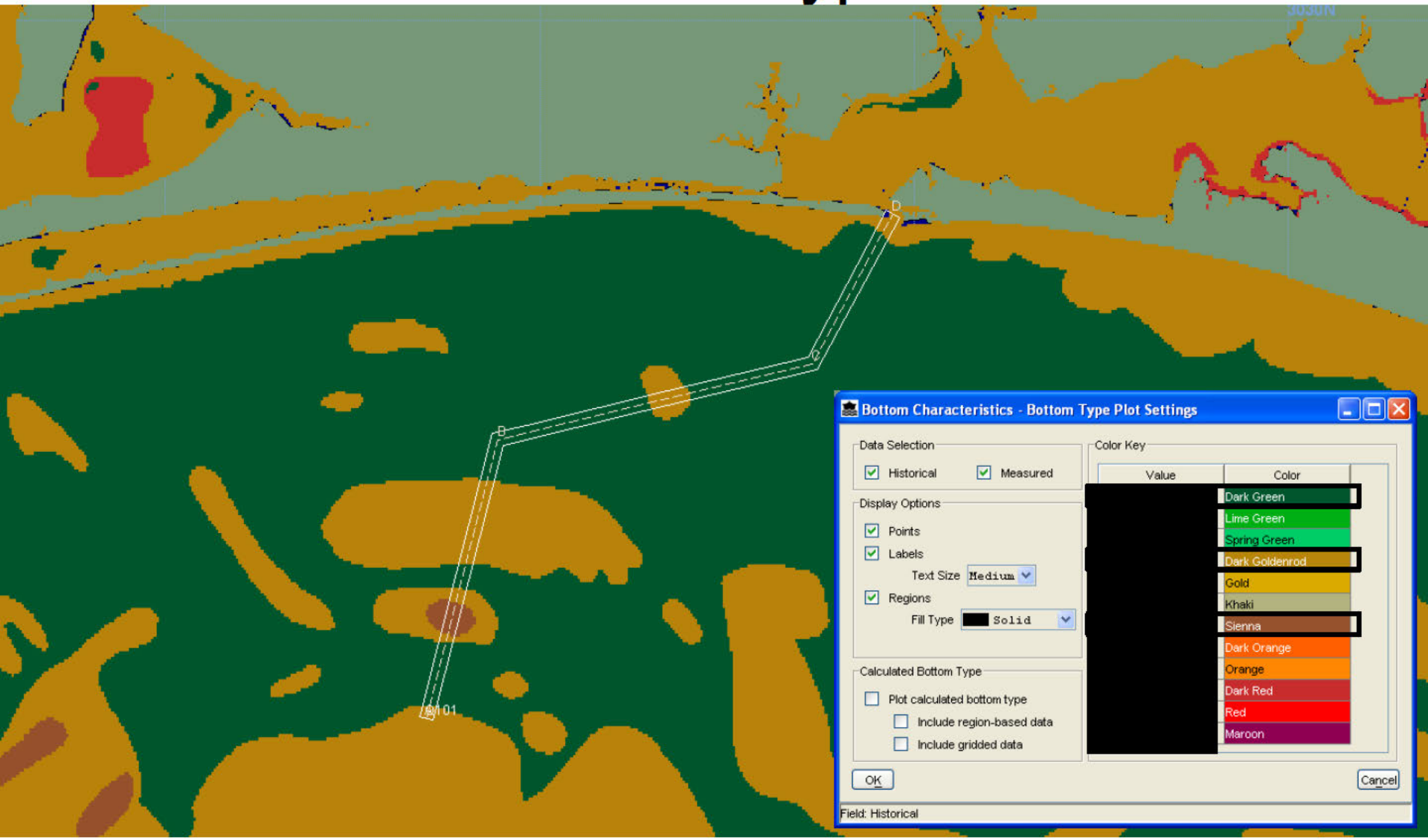
Platform and Equipment

- Platform refers to the vehicle (aircraft, ship, UUV, UAV) towing or containing the MCM equipment
  - Most platforms have limitations
  - Airborne platforms have limitations
- Equipment refers to the actual MCM sensor
  - Search, identify, and neutralize equipment
    - Search – Detect and/or Classify Mine-like Objects
    - Identify – Identifies objects as mine or non-mine
    - Neutralize – Renders the mine inactive
  - Mechanical Sweep equipment
    - Cut mooring cables on moored mines
      - Result in floating mines which need neutralization
  - Influence Sweep equipment
    - Magnetically and/or Acoustically trick mine logic into detonating

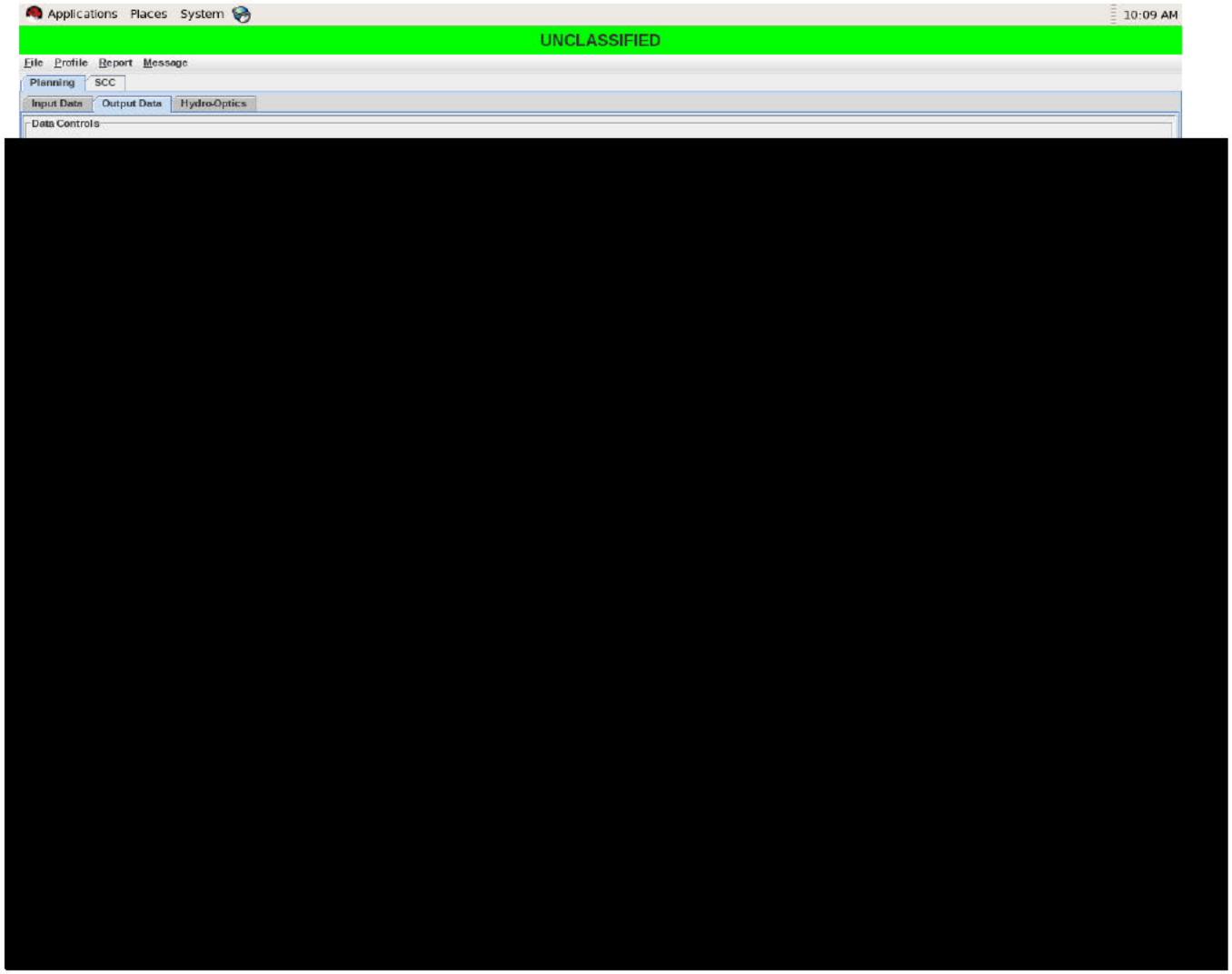
Assessing the Mine Hunting Environment

- Search Systems
  - Sonar systems can be affected by varying environmental conditions
  - Electro-optical systems performance can be affected by varying environmental conditions
- Identification Systems
  - Camera and Diver's performance are affected by varying environmental conditions
  - Electro-optical system's performance are affected by varying environmental conditions
  - Sonar system's performance are affected by varying environmental conditions

Bottom Type


Bottom Characteristics - Bottom Type Plot Settings
Data Selection
Historical
Measured
Display Options
Points
Labels
Text Size
Medium
Regions
Fill Type
Solid
Calculated Bottom Type
Plot calculated bottom type
Include region-based data
Include gridded data
Color Key
Value
Color
Dark Green
Lime Green
Spring Green
Dark Goldenrod
Gold
Khaki
Sienna
Dark Orange
Orange
Dark Red
Red
Maroon
OK
Cancel
Field: Historical

Sound Velocity Profile



Search Equipment

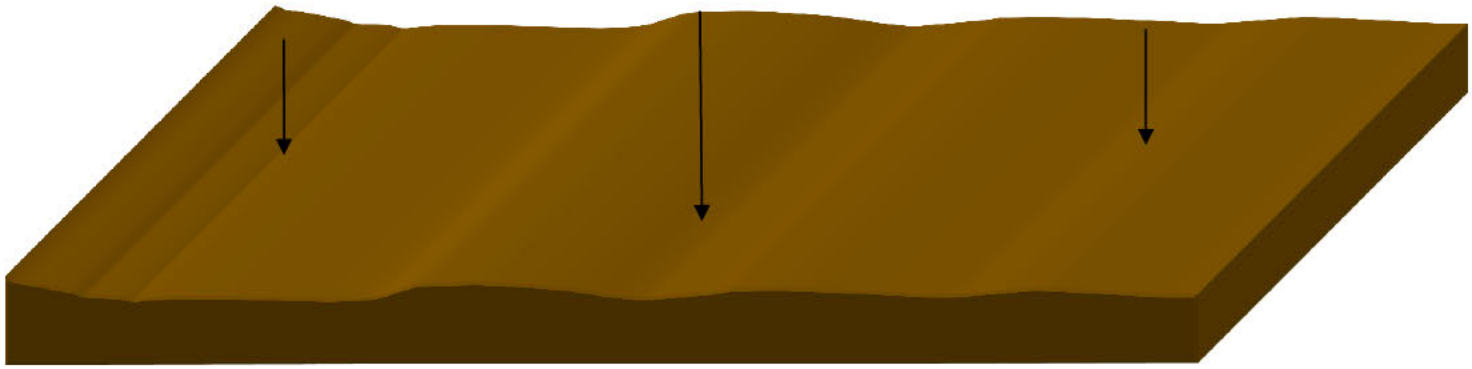
- A system that uses acoustic, visual, or electro-optic measures to search for mine-like objects
- Search systems must be planned carefully to balance missed mines and false contacts
- Each search system has one or multiple systems that follow behind in order to identify and if required, neutralize any mine-like objects found, this is referred to as Kill Chain
- Search equipment can either search the entire water column, or have different configurations to search different parts of the water column
  - Search equipment configuration depends on water depth and expected mine location
- Bottom mines are searched with equipment
  - Mine-like objects are identified by follow-on systems (i.e., identification or neutralization equipment)
- Moored mines are searched by methods which cover the large amount of the water column
  - Mine-like objects are identified

MCM Hunting Moored Mines

- Some factors impact performance
- Mine properties affect performance
- Analyze environment to determine performance
- Result may vary between mine type and environment
  - Each mine will have its own clearance effort

MCM Hunting Bottom Mines

- Bottom Topography affects performance
  - Bottom roughness
  - Amount of bottom clutter
- Environment
  - Analyze environment to determine performance
- Result may vary based on mine type and environment
  - Each mine will have its own clearance effort



Mechanical Sweep Equipment

- A system that tows a wire with attached cutters which cut moored mine cables
- Mechanical sweep systems must be planned carefully in order to place sweep appropriately
- After the system sweeps the mine, follow on activity is planned to neutralize the floating mines

Mechanical Sweeps

- Performance is based on certain factors and impacts
  - Sweep
  - Cutters
- Environment

- Mechanically cut mines become floating mines
  - Must have method for tracking and neutralization

Influence Sweep Equipment

- A system that emits magnetic and/or acoustic noise
- Influence sweep systems are dependent on certain factors
- Influence sweep systems must be planned carefully in order to take into account for counter countermeasures

[redacted]

Influence Sweeps

- Influence sweeps are chosen based on threat mines
- Environment
  - Magnetic and Acoustic Environments are currently defined as good, nominal, and poor

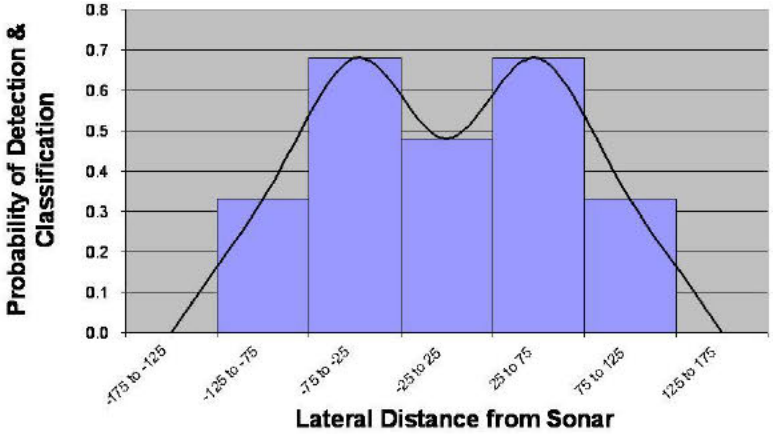
Equipment Configuration Considerations

- Evaluation Limitations
  - Environmental
- Evaluate Time
  - Evaluate Platform Time on Station
  - Evaluate Post-Mission Analysis (PMA) Time
  - Evaluate Entire Kill Chain (Detect to Engage Timeframe)
- Evaluate Performance
  - Search Environment
  - Mine Type

MCM OPERATIONAL PLANNING
SCHEDULING

Search Equipment Performance

- MCM Performance is defined for each equipment configuration on each platform against all mine types
  - Performance parameters are defined as probabilities
  - Search systems are the probability that if the equipment passes over the mine then the probability that the equipment detects the mine (P_d)
    - Some search systems also classify, so this becomes the probability that if the equipment passes over the mine, the probability that the equipment will detect and classify the mine correctly (P_{dc})
    - Search performance is calculated using empirical data and/or modeling
  - Definition of "if the equipment passes over the mine" is width calculated based on performance statistics, it is referred to as characteristic search width (A)

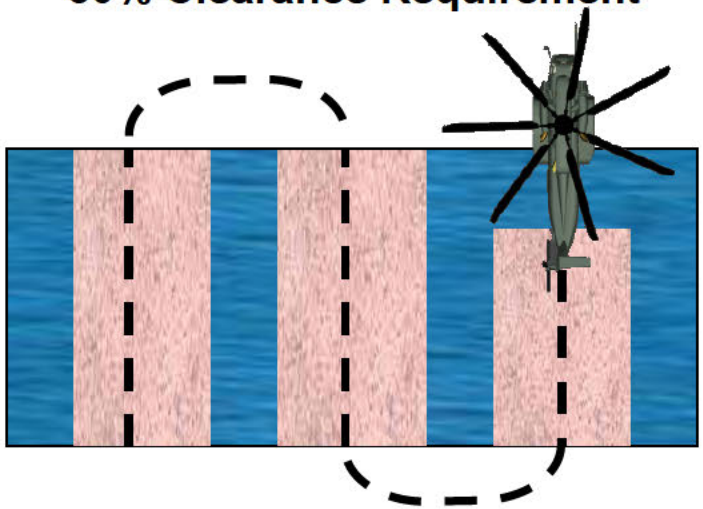


Track Planning

- Planning routines use performance parameters (P_d, P_{dc}, B, and A) to determine spacing of tracks in order to meet required percent clearance
- Percent clearance is the <u>average</u> cumulative probability
- Tracks are overlapped or separated depending on the relationship of the probability (P_d, P_{dc}, B) to the percent clearance
  - Probability of detection of 0.8 with required percent clearance of 0.85 will require overlapping of effort
  - Probability of detection of 0.8 with required percent clearance of 0.50 will allow for gaps in effort
- Planning routines take into account other factors, but those will be discussed separately

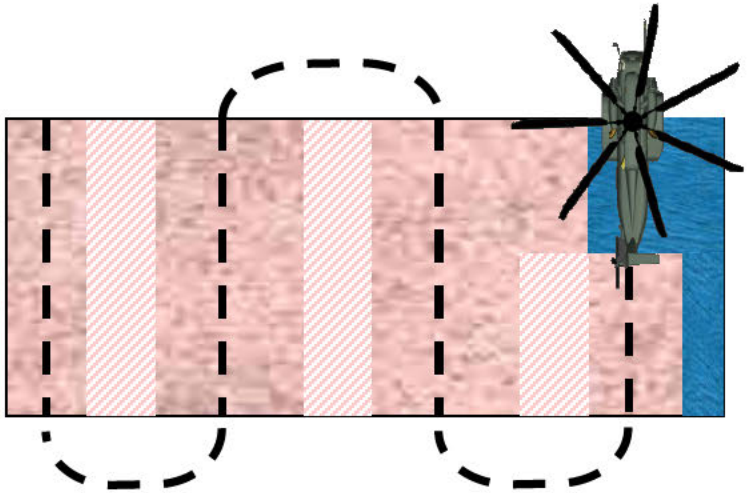
Example Track Spacing

Sampling
50% Clearance Requirement



Average Clearance across area is 50%

Overlap
85% Clearance Requirement



Average Clearance across area is 85%

80% 83%

System Water Depth Capabilities

System	Water Depth, Minimum (ft)	Water Depth, Maximum (ft)
Sonar SPS System		
Sonar VOL System		
Laser System		
Influence Sweep		
Neut System		

Capability of Equipment Versus Mine

Mine	Sonar SPS System	Sonar VOL System	Laser System	Influence Sweep	Neut System
Bottom Mine					
Moored Mine					
Near Surface					

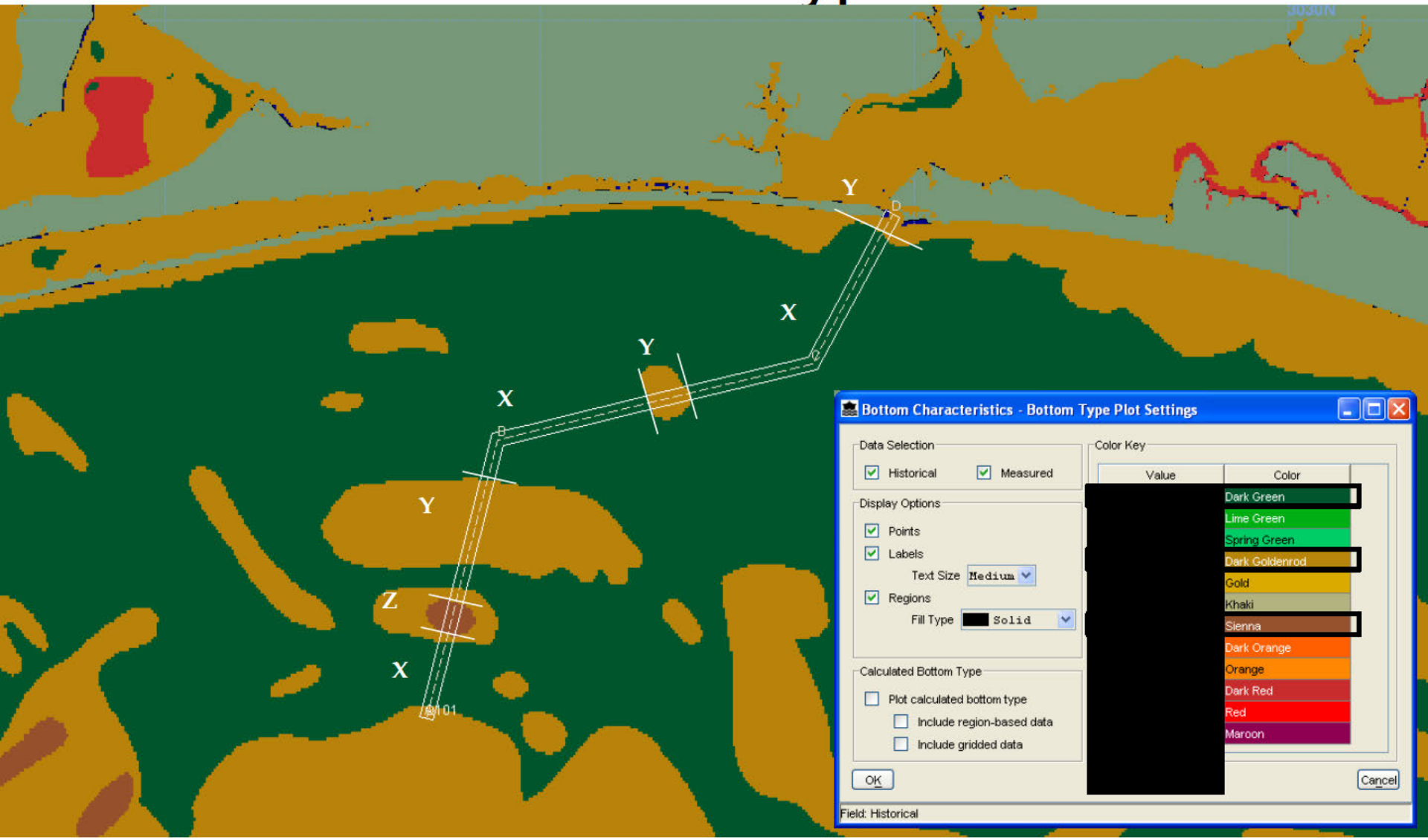
MCM Planning

- Determine best (most efficient) combination of platform equipment configurations in order to meet MOP
- MOE are usually defined by timeframe and risk
  - Example: X weeks and Y% remaining risk
- Calculate performance for each equipment configuration, in each area in which it is effective and against each mine
- Given system performance, MOE, and sortie time, calculate size of MCM area that can be completed
- Time considerations
  - Identification time for clutter that are non mines
  - Transit time
  - Deconfliction
  - Time on station
  - PMA
  - Night time limitations
  - Kill chain

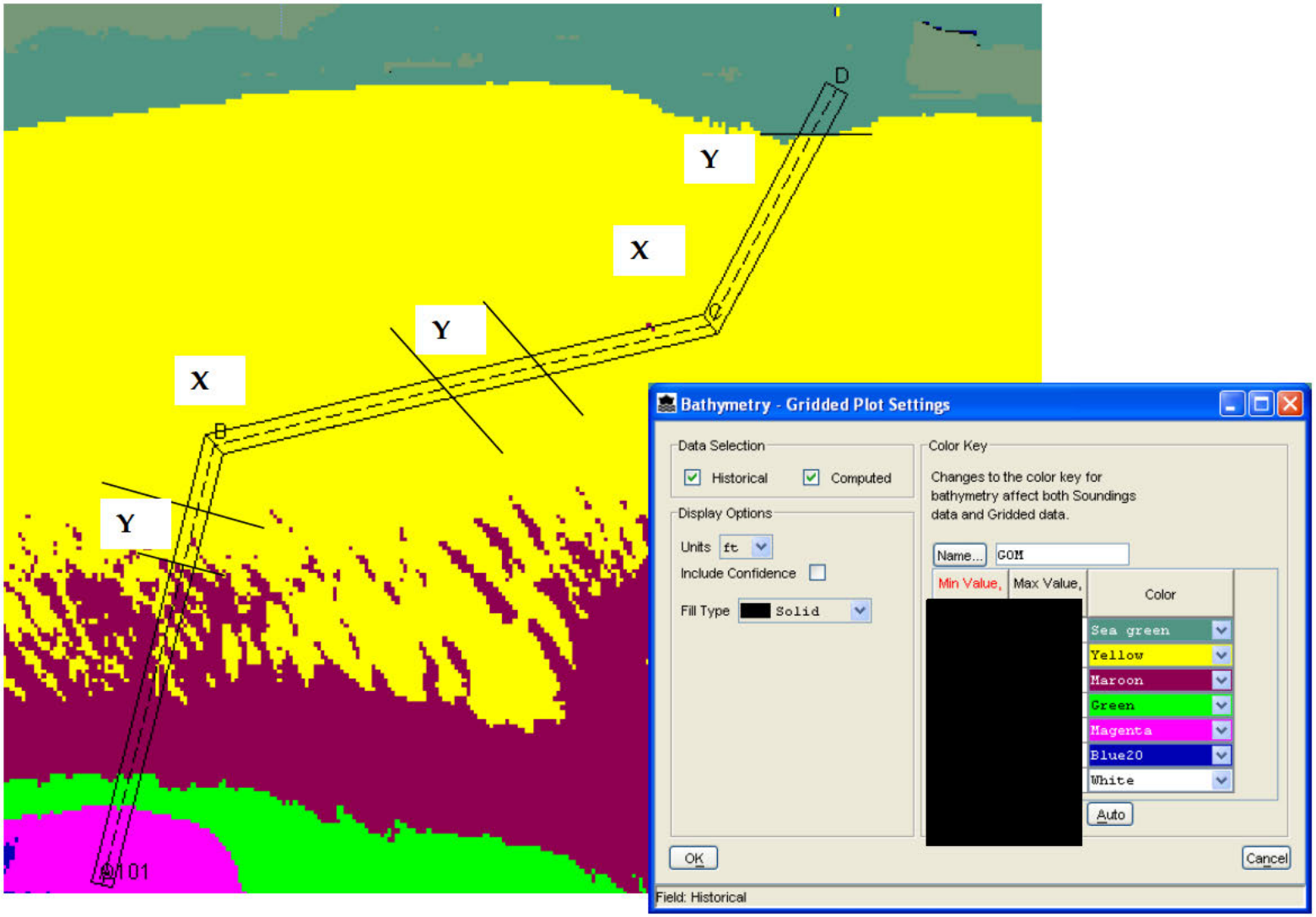
MCM Plan Segmentation

- MCM areas should be sub-segmented based on environment, mine threat, transit ship risk, and equipment time
- Segmentation is a three dimensional problem
  - Segmentation can be different throughout the water column
  - Near Surface, Volume, and Bottom
    - For example:
      - Near Surface mines may have 7 nmi segments while bottom mines may have 1.2 nmi segments
      - Near Surface equipment may be faster and/or bottom equipment may have poor performance
- Segmentation is a major part of planning and has a large impact on efficiency
  - No tools exist to assist planner in segmenting

Bottom Type


Y
X
Y
X
Y
Z
X
Bottom Characteristics - Bottom Type Plot Settings
Data Selection
Historical
Measured
Display Options
Points
Labels
Text Size
Medium
Regions
Fill Type
Solid
Calculated Bottom Type
Plot calculated bottom type
Include region-based data
Include gridded data
Color Key
Value
Color
Dark Green
Lime Green
Spring Green
Dark Goldenrod
Gold
Khaki
Sienna
Dark Orange
Orange
Dark Red
Red
Maroon
OK
Cancel
Field: Historical

Sub-Segment for SPS System

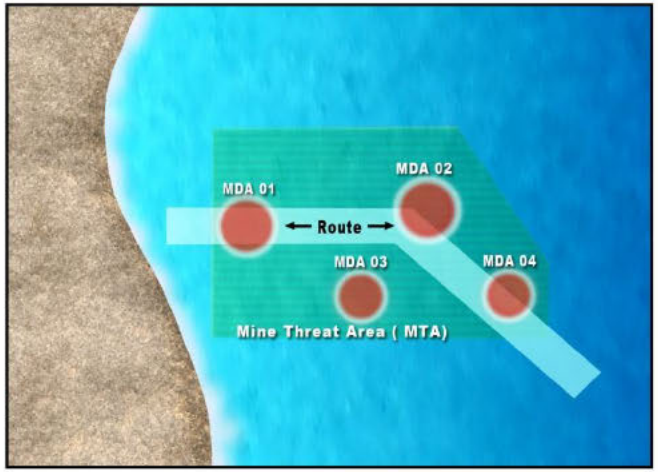


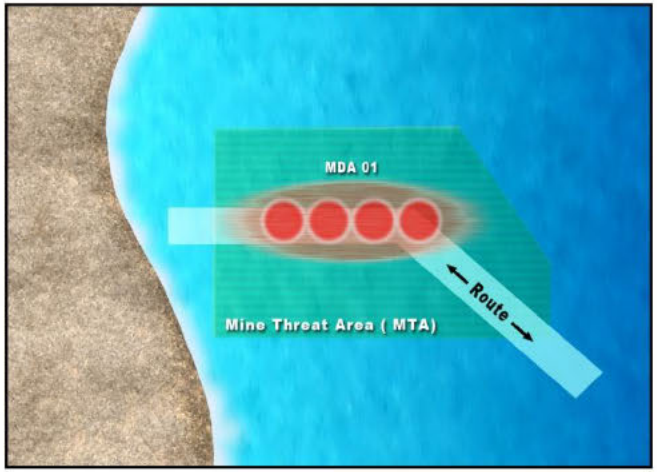
Additional MCM Area Considerations

- Additional areas may be required depending on objective
  - Route that requires fire support protection may need fire support boxes
    - Force protection boxes are usually N yards wide
      - Fire support boxes must be added at intervals along the route in order to provide protection
  - May require boxes along the route in order to support MCM operations
  - MDAs
    - Planning can be done for exploratory operations, but it is difficult to plan for MDAs
      - Mine locations are not known at the planning phase
      - Location and its associated environmental conditions will impact choice of equipment
      - Must plan for potential MDAs in order to estimate total mission time

MDA

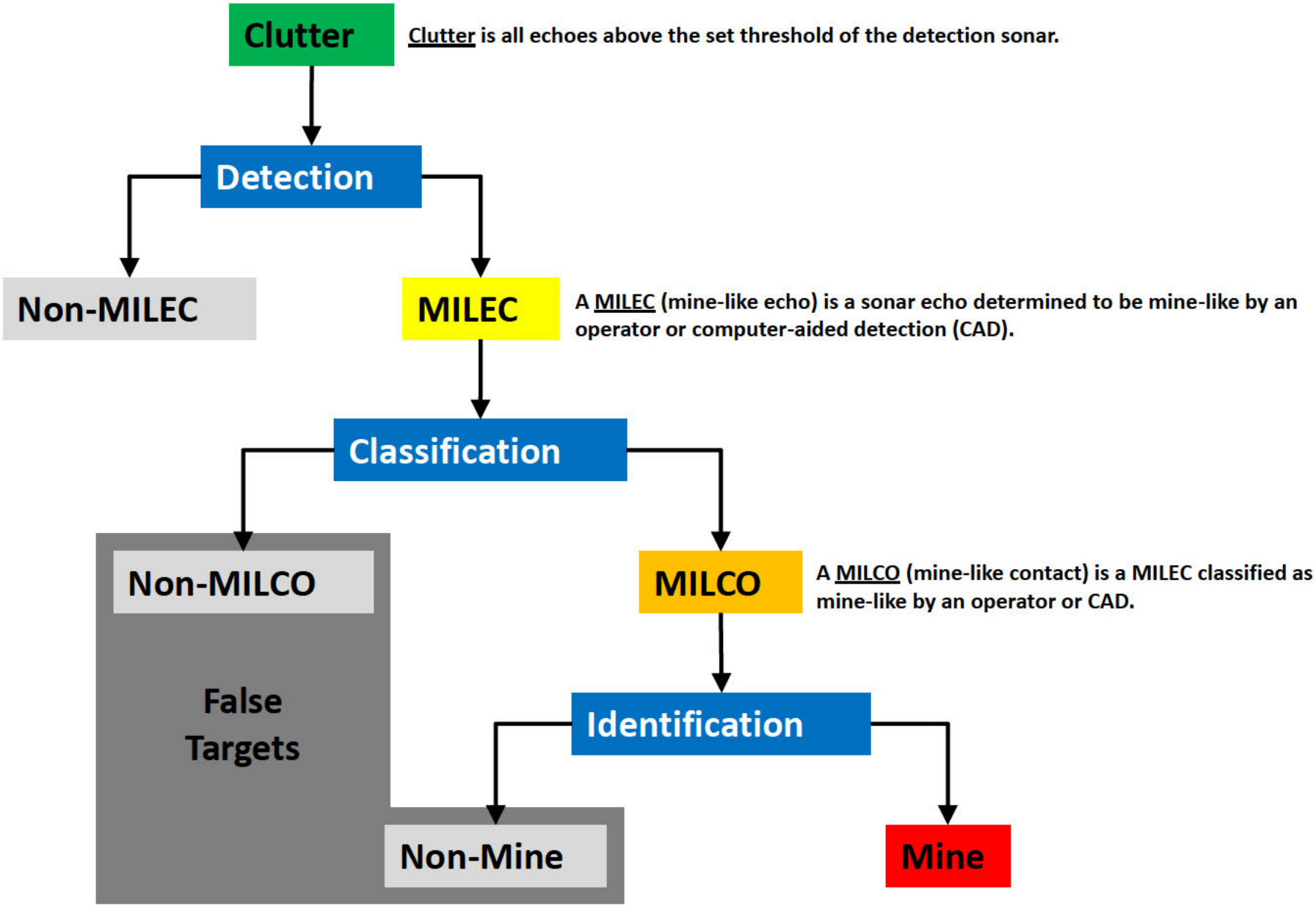
- The calculated size and shape of the MDA should be related to the threat and based upon experienced military judgment. Care should be taken not to draw the limits of the MDA larger than necessary. As MCM operations progress the MDAs may be expanded, reduced, cancelled, or combined as necessary.





Impact of Contacts

- Equipment spend time identifying and neutralizing mine-like contacts and false targets


Clutter
Clutter is all echoes above the set threshold of the detection sonar.
Detection
Non-MILEC
MILEC
A MILEC (mine-like echo) is a sonar echo determined to be mine-like by an operator or computer-aided detection (CAD).
Classification
Non-MILCO
MILCO
A MILCO (mine-like contact) is a MILEC classified as mine-like by an operator or CAD.
False Targets
Identification
Non-Mine
Mine

Equipment Schedule

- Laser System
  - One pass based on percent clearance required – determine clutter
  - to determine mine-like contacts
  - Neutralization system identifies mine-like contact as mines or non-mines
    - Create MDAs for mines
- Sonar SPS
  - One pass based on percent clearance required
    - Create MDAs for mines
  - Neutralization System neutralizes sonar SPS mines
- Sonar VOL
  - One pass based on percent clearance required
  - Neutralization system identifies mine-like contacts as mines or non-mines
    - Create MDAs for mines
  - Neutralization system neutralizes sonar VOL mines

Schedule – COA

- Schedule can be compiled once all the segmentation, performance estimate, and time considerations have been collected
- Initial schedule will have to consider most efficient equipment, proximity of equipment, egress and ingress, deconfliction from other equipment, time to identify clutter, Kill Chain, and MDAs
- Schedule is an important and difficult bookkeeping effort
- Schedule can be input into evaluation tools to review outcome
- Different schedules (i.e. Courses of Action (COAs)) are required
  - Demonstrates analysis of options and justification for chosen COA

Creating the MCM Plan
Hunting versus Sweeping

Mine Hunt When:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

Mine Sweep When:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

Final Thoughts about Operational Planning

- Initial planning is difficult and time consuming
- Initial plan is hardly ever the plan used in operation, after operation begins conditions usually change
  - CASREP to equipment
  - Weather
  - Environmental conditions are not as expected
  - New mine threats are discovered
  - Mine-like contacts
- Running Estimate must be kept in order to maintain an operational picture
  - Re-planning must be done based on changing conditions
  - Re-planning is very similar to initial planning
    - Time consuming and difficult

Planning Tools

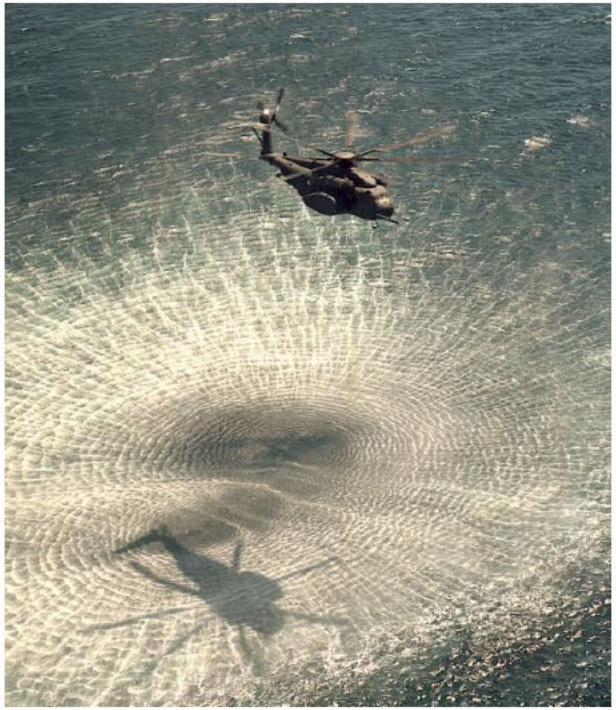
- Mine Warfare and Environmental Decision Aids Library (MEDAL)
  - Display environment conditions (if available)
  - Display mine threats (if known)
  - For each equipment
    - Pull Performance (P_d, P_{dc}, B, and A)
    - Calculate track spacing and sortie time
  - Display a schedule
- Route Planner
  - Plan Egress and Ingress routes
  - Calculate total time
- Work flows that assist in picture appropriate threat/equipment configurations which will help generate schedules

MCM PLANNING THEORY

PERFORMANCE PARAMETERS

Performance Parameters

- Equipment or system effectiveness is measured in terms of
  - Probability it successfully carries out its tasks
  - Time it takes to carry out its tasks
  - Amount of “bad” information it introduces into follow-on work
- During system development, performance parameters are derived that are used in planning and evaluating MCM missions

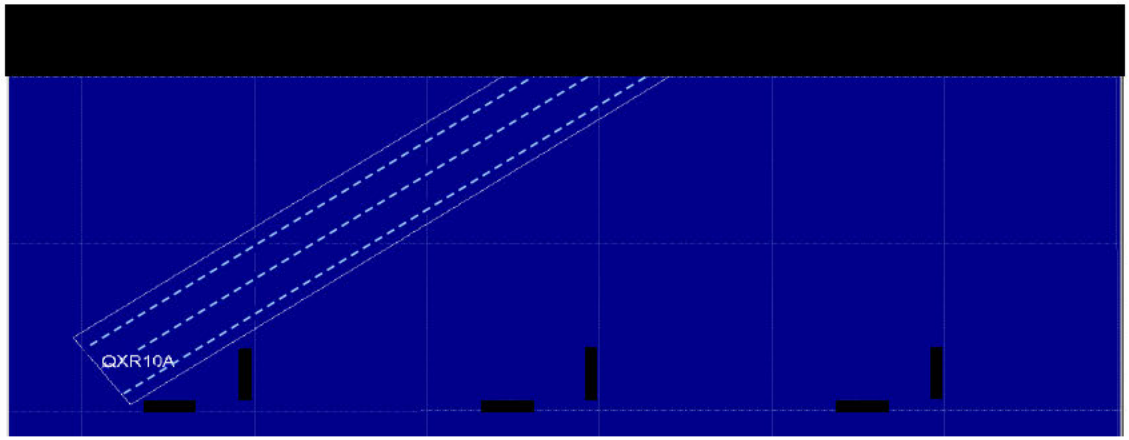


Lateral Range Curve or P(y)

- Probability of sweeping, or detecting / classifying a mine at a lateral offset, *y*, from the sweep or sonar in one pass of the sweep or sonar by the mine
- Simplified terms: Describes the path width of a sweep or sonar against a mine
- P(y) depends upon many conditions
  - Equipment characteristics
  - Environment
  - Mine type
- Systems have multiple P(y)s

Track Layout

- Track layout is dependent on required percentage clearance, performance of the system (A and B) and the navigational error
  - Common tool for calculating track layout



Percent Clearance

- Percent Clearance is a statistical measure of the expected fraction of mines removed
  - Literally it is defined as the average cumulative probability across the area

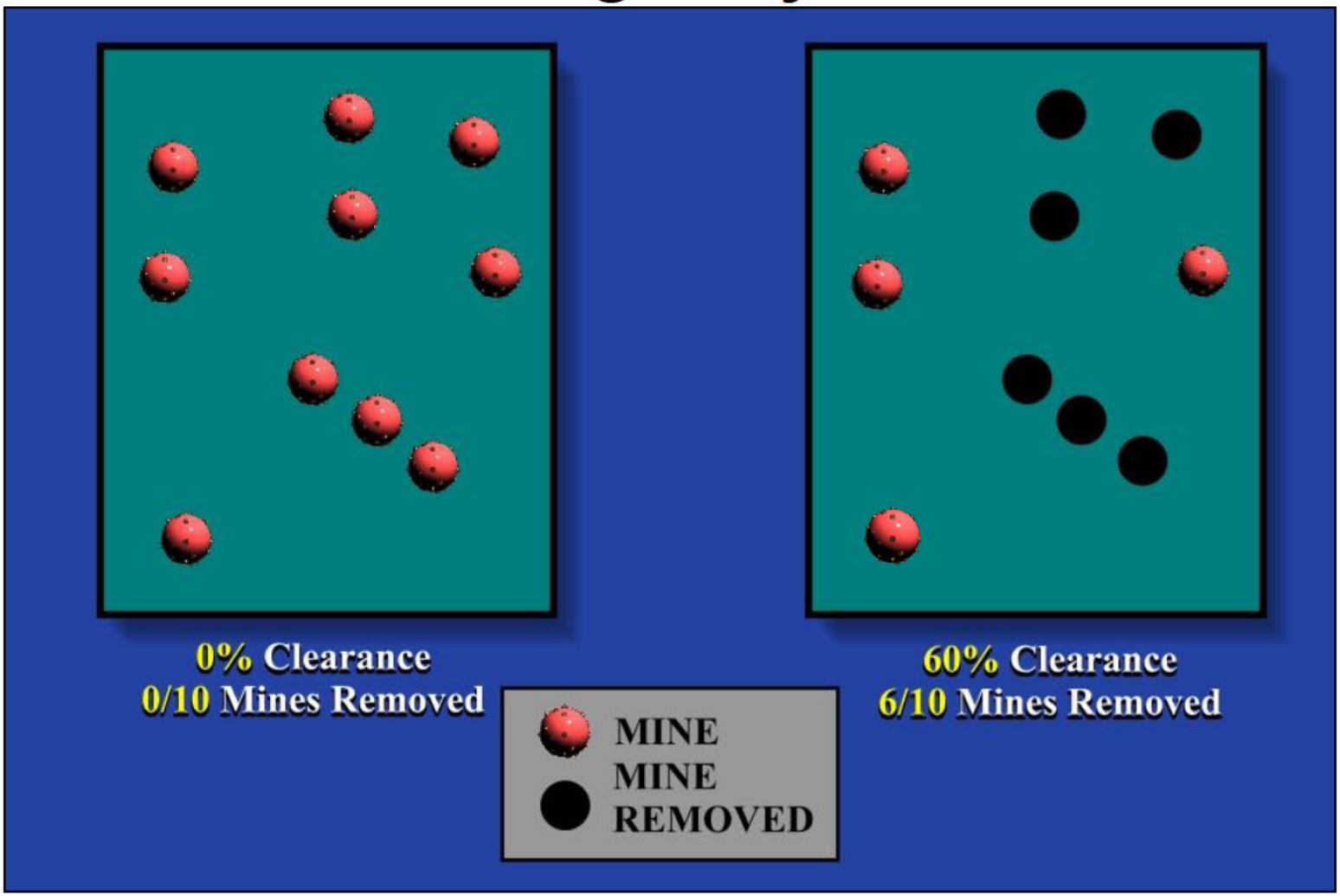
Some Facts About Percent Clearance

- Quantity used by planners and evaluators
  - Used to describe results of planned and completed MCM work
- It is a key parameter in estimating time and risk
  - Directly related to the amount of work
  - It carries the implication that a percent of the mines have not been removed
- Higher Percent Clearance, the longer it will take to complete the MCM operation

Planning and Evaluation

- Planning/Replanning
  - Given a desired *P*, find a **track layout** that will achieve it
  - UCPLN
  - Optimization Planner (OPTPLN)
- Evaluation
  - Given a **track layout**, determine the *P* obtained
  - Non-Uniform Coverage Evaluation (NUCEVL)
  - Analytic Bayesian Coverage Evaluator (ABCE)

Clearing Objective



Some percent of the mines will be or are removed.