



Acoustic Mine Detection Overview and Requirements

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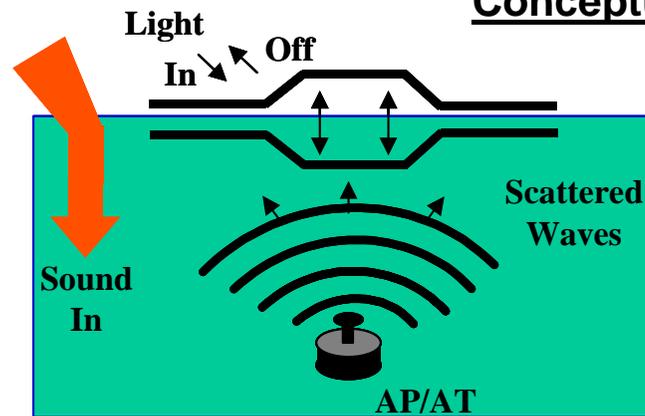
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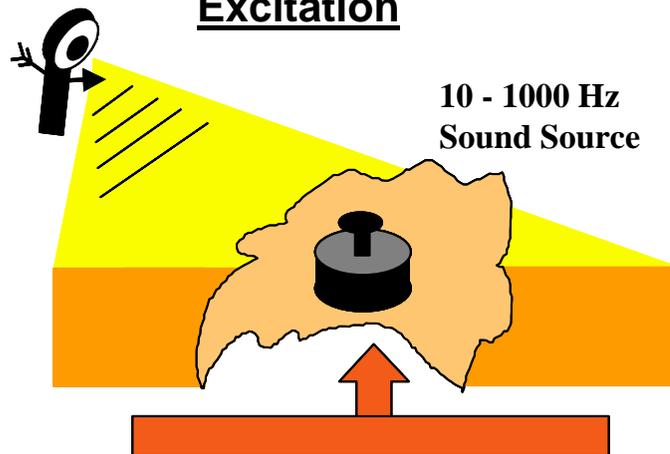
Conceptual Model: Acoustic Mine Detection



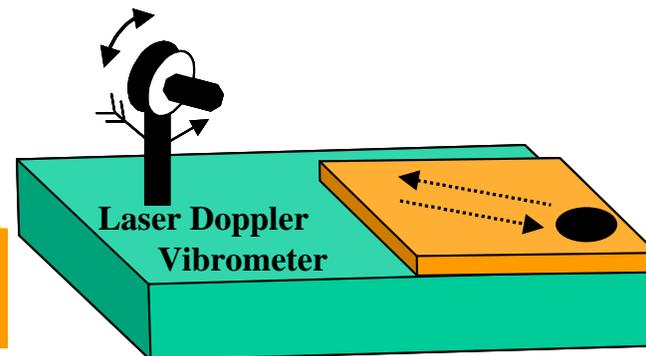
Conceptual Model



Excitation



Detection



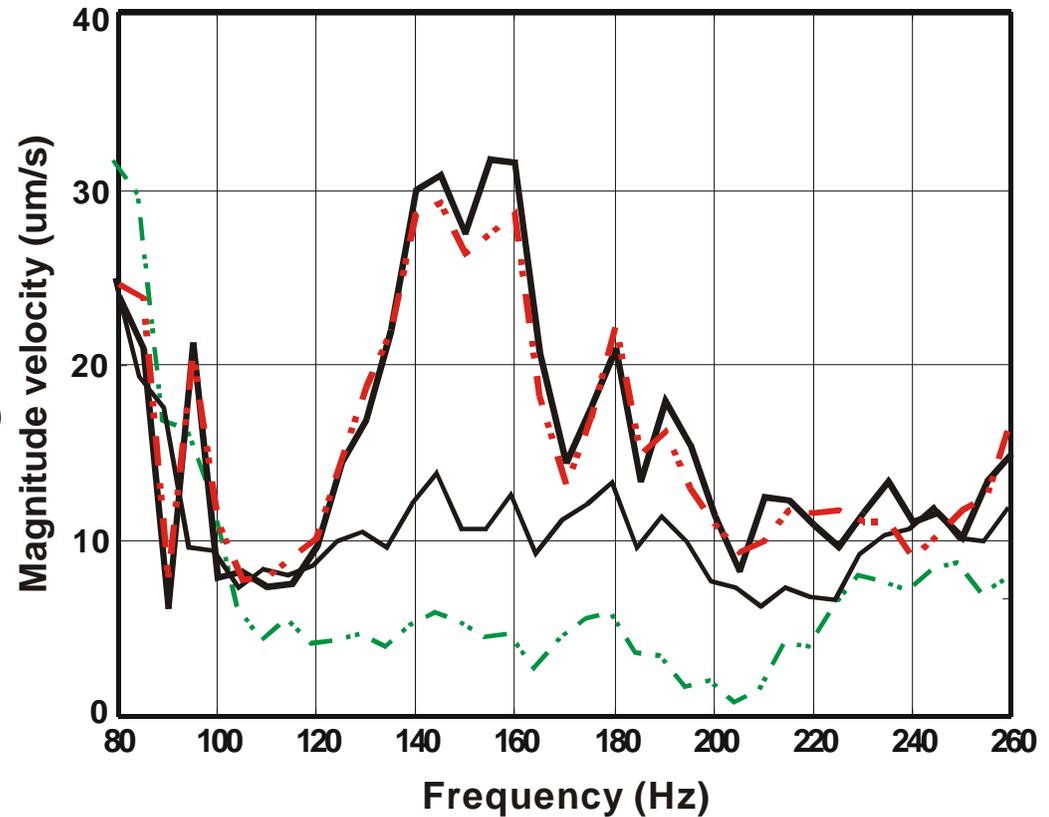
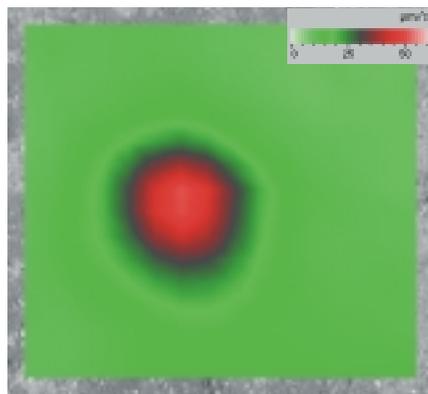
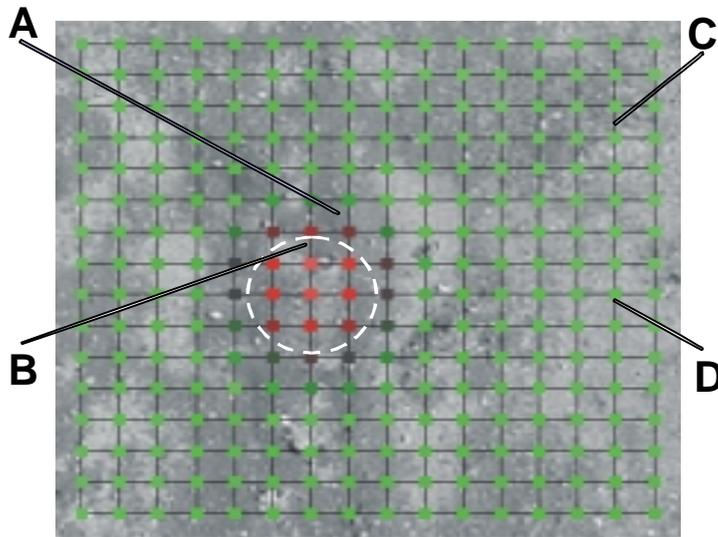
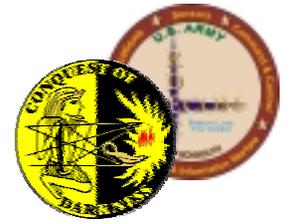
Experimental Findings: University of Mississippi



- Linear mine detection.
- Excitation: broadband noise with frequency content between 50 and 1000 Hz.
- Acoustic excitation couples into the soil causing the buried mine and the soil surrounding it to vibrate.
- LDV used to measure surface velocity of the soil

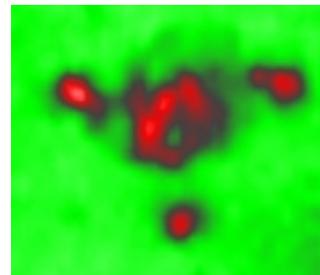
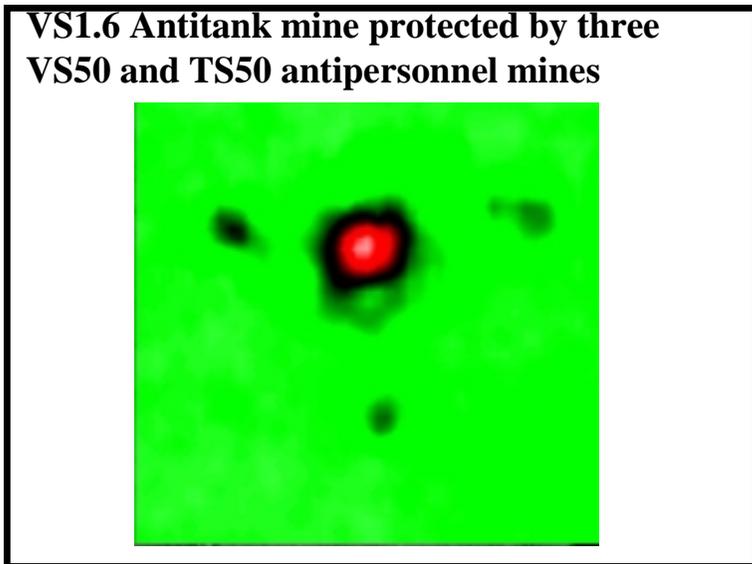
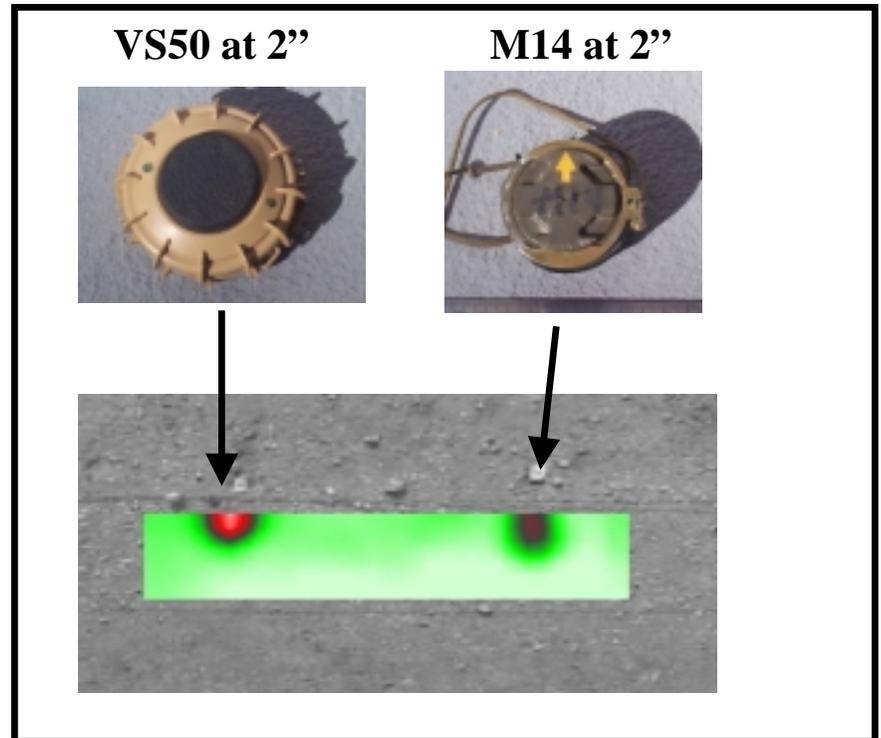
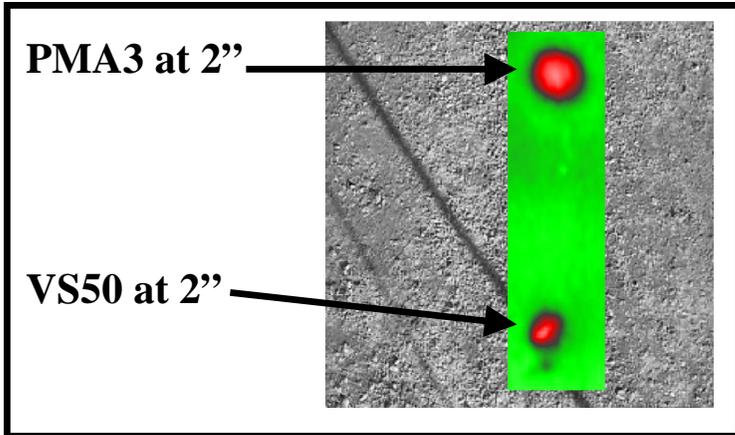


Experimental Findings: Stop & Stare Scanning



Mine: M21 (Metal AT 9 in diameter) at 4 in
Area: 1m x 1m
Frequency: 140 – 160 Hz

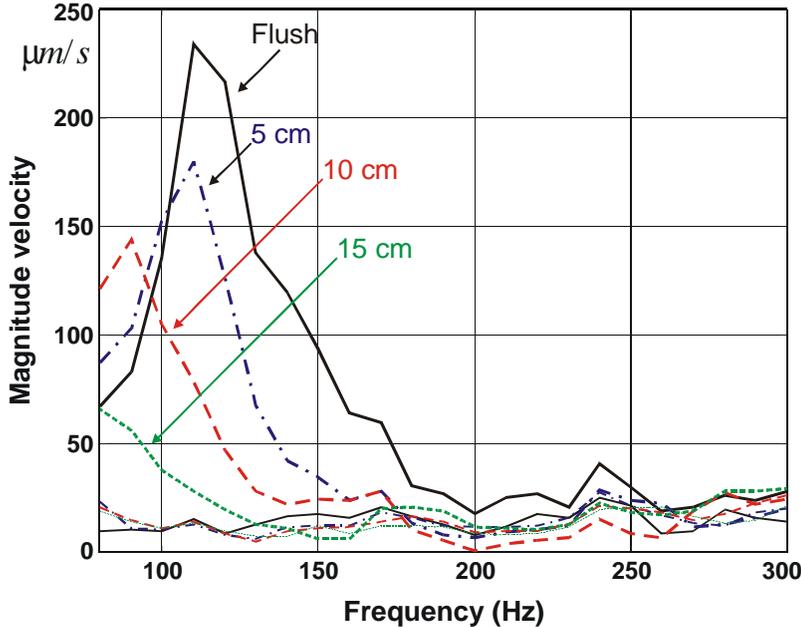
Antipersonnel Mine Detection



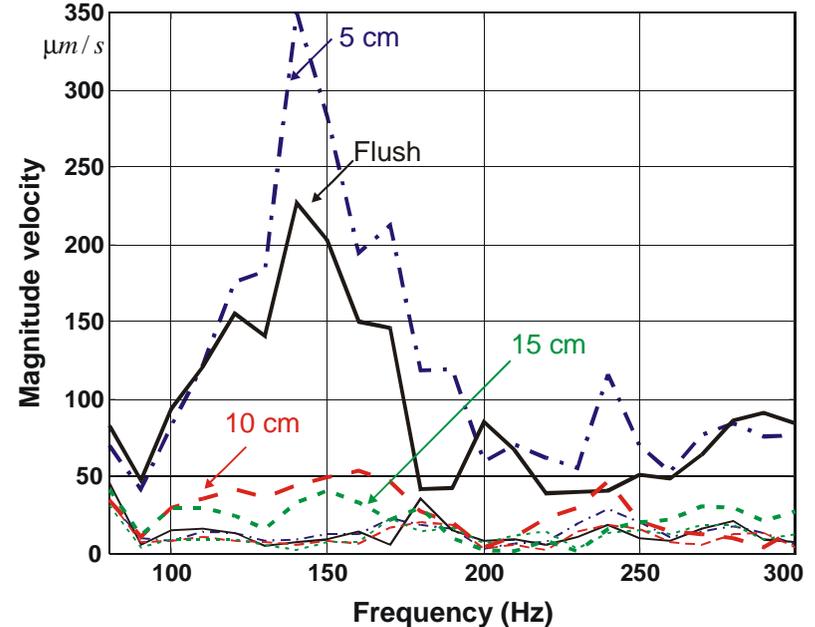
Experimental Findings: University of Mississippi



VS2.2s in Gravel



VS2.2s in Dirt

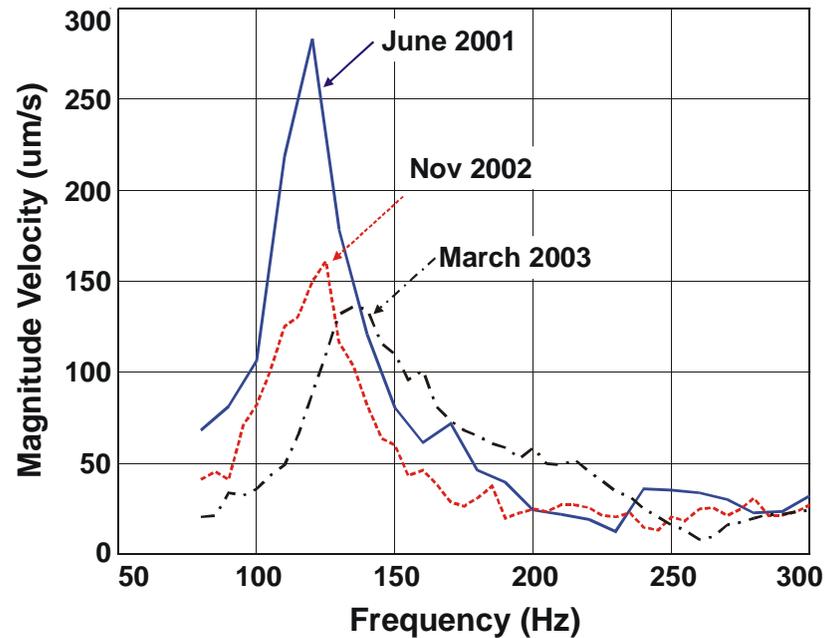


Vibration response of a buried mine is a function of both burial depth and soil type.

Experimental Findings: University of Mississippi



VS2.2 at 5 cm in Gravel

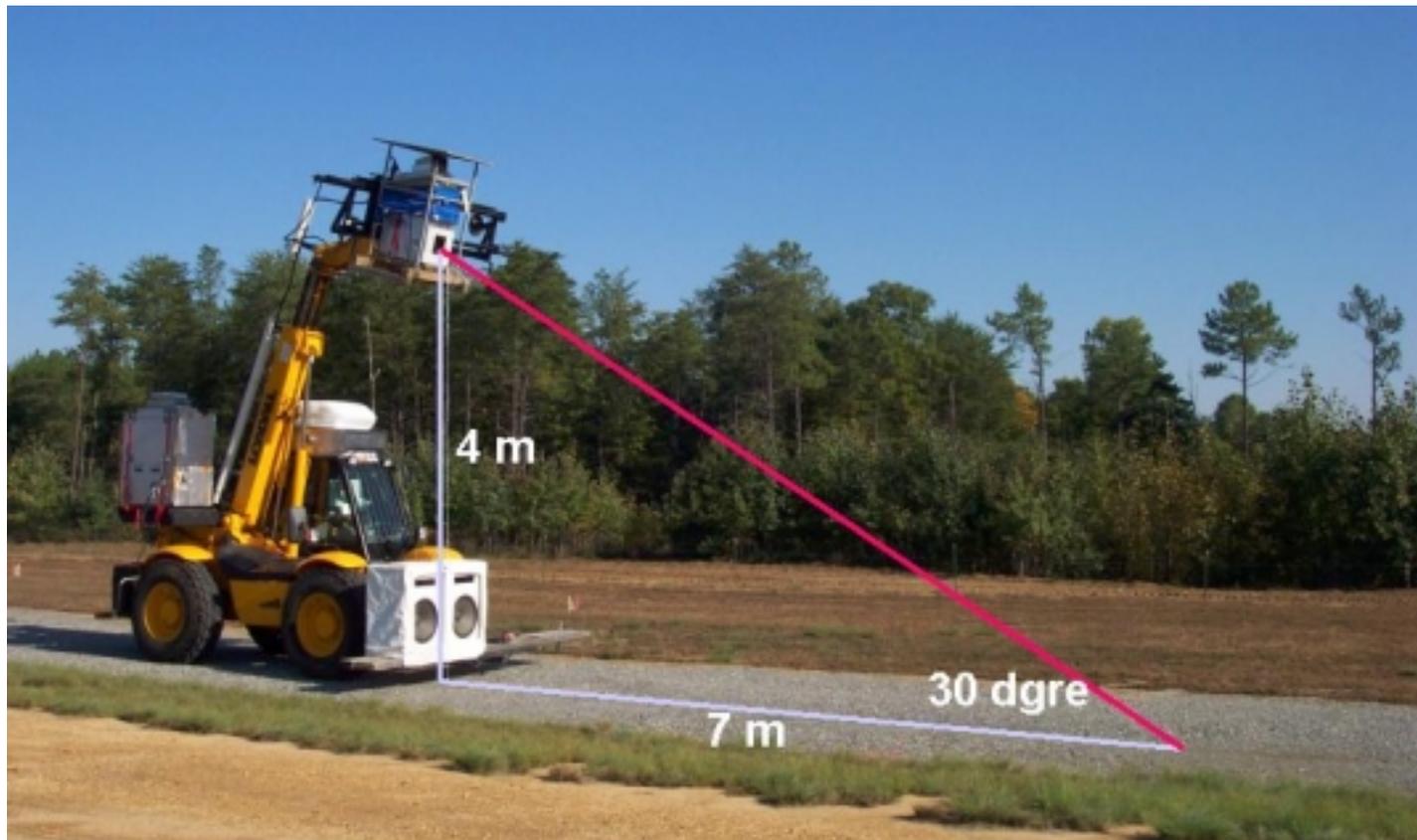


Vibration response of a buried mine is also a function of environmental conditions.

Technology: Forward Looking



Forward Looking Field Apparatus



Technology: Forward Looking



Forward-Looking 2002 (Fort A.P. Hill Lane 19)

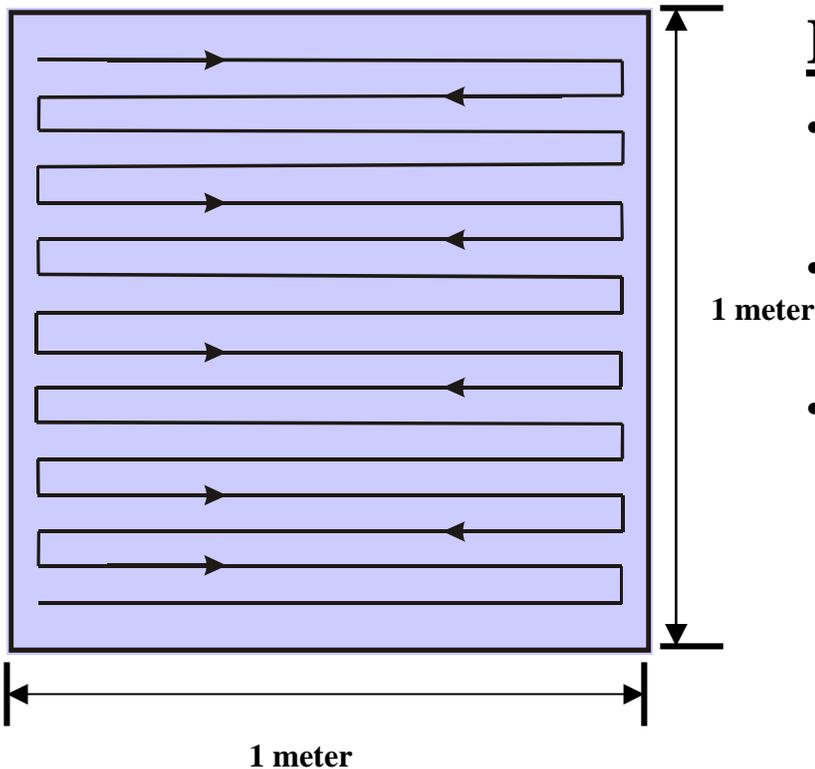
Stand-off: 7 m

- Beam Angle: 33°
- Moving beam
- Scan speed: 0.1 m / s
- Sound level at target: 75 dB
- Sound source: On the vehicle

Stand-off: 2 m

- Beam Angle: 51°
- Moving beam
- Scan speed: 0.1 m / s
- Sound level at target: 100 dB
- Sound source: On the vehicle

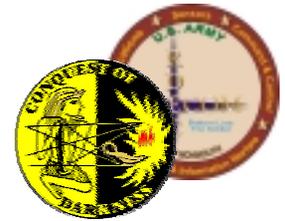
Technology: Forward Looking



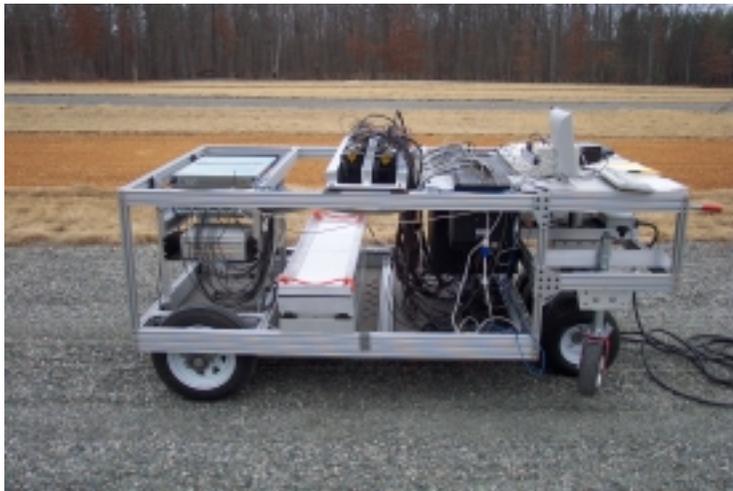
Moving Beam Scan

- Beam moving at constant speed across each line
- Sound source radiating Pseudo-random noise
- Measuring surface velocity response (in time) during beam-moving

Technology: Downward Looking



Multiple LDV Cart

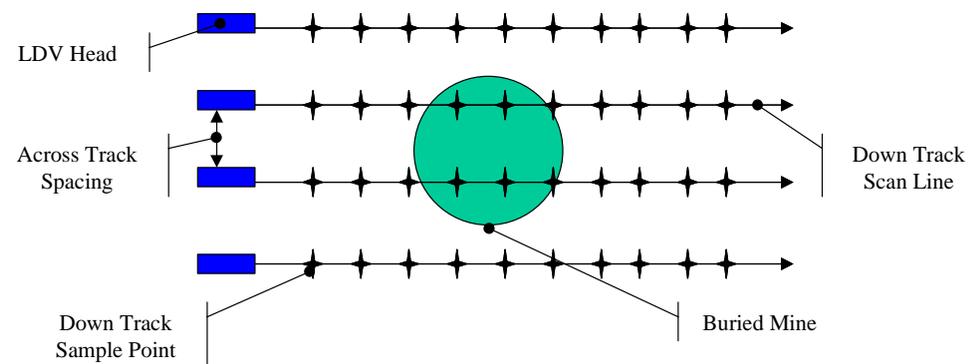


Side View of Mobile Platform

LDV Laser Heads



Data Track Concept

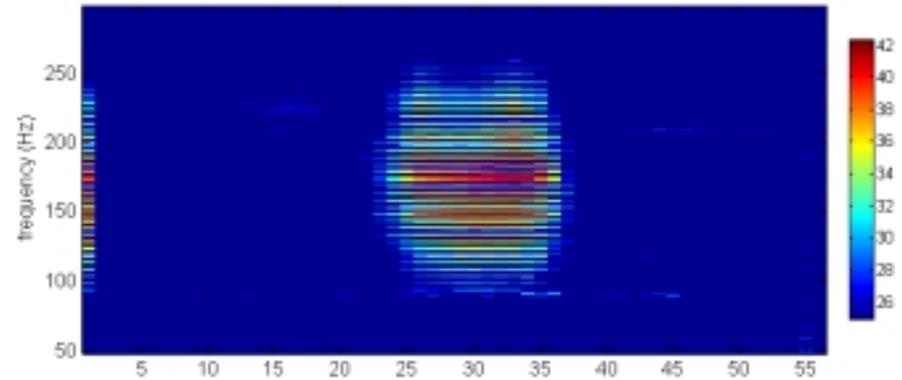


Technology: Downward Looking

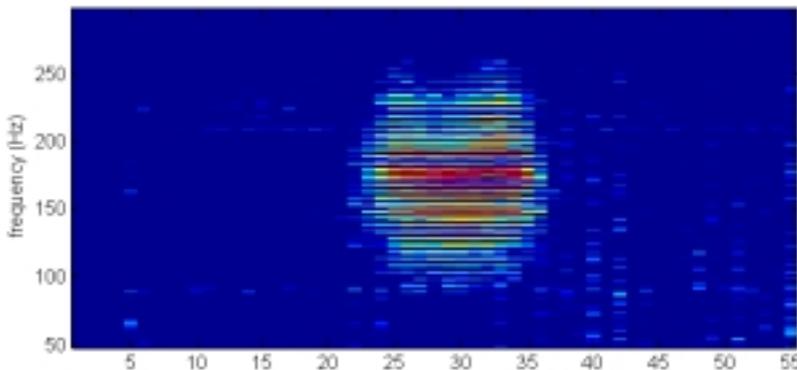


Results (Speed Variations)

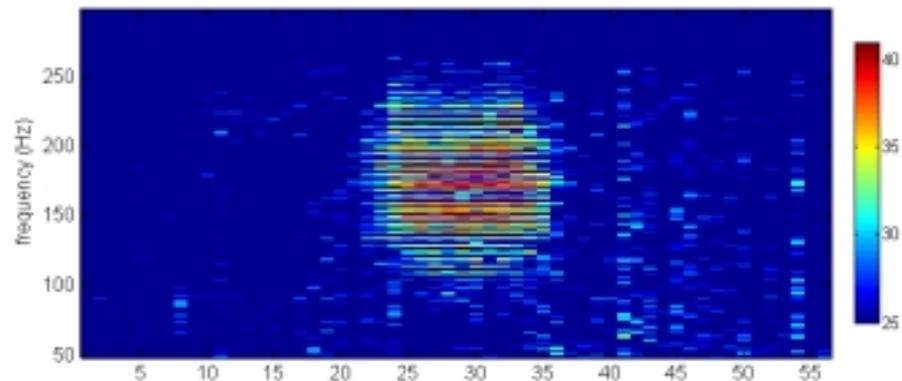
- Single LDV head.
- Scans of a flush buried VS 2.2 (plastic AT mine) at 0.037, 0.07, and 0.1 km/hr.



Position, $\Delta x = 2$ cm



Position, $\Delta x = 2$ cm



Position, $\Delta x = 2$ cm



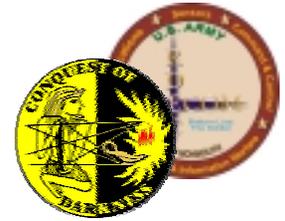
Phenomenology: Acoustic Mine Detection

- Acoustic excitation (e.g. linear sweeps, broadband noise, two tones) couples into the soil causing the buried mine and the soil surrounding it to vibrate.
- Whether excited acoustically or seismically, the vibration response of the mine is different from the soil surrounding it.
- Complex construction of mines leads to structural resonances.
- Soil vibration is currently measured using a Laser Doppler Vibrometer (LDV).

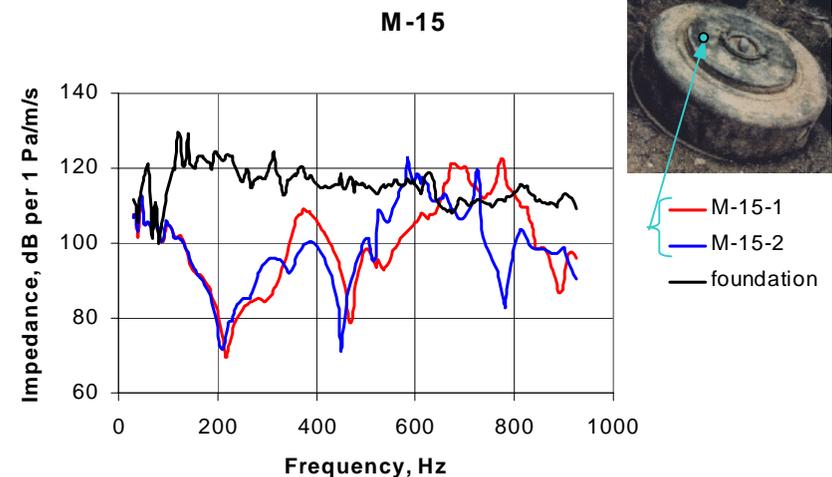
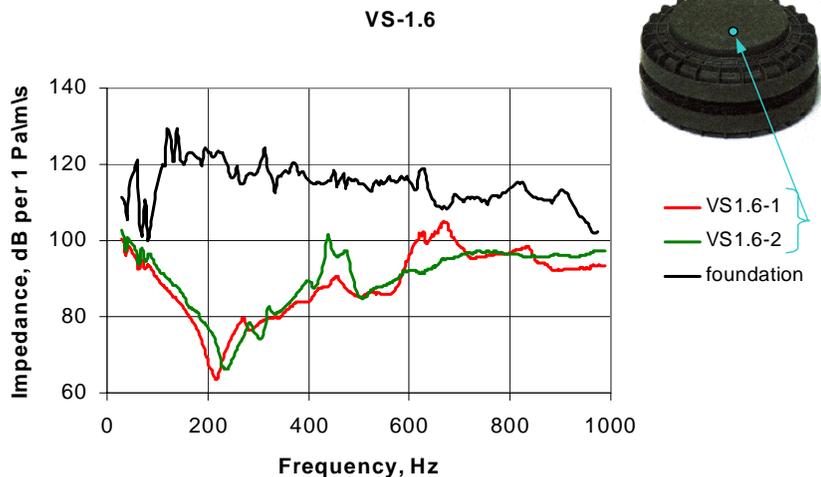
University of Mississippi: Linear detection.

Stevens Institute of Technology: Non-linear detection.

Phenomenology: Landmine Structural Resonances



- Researchers at the Stevens Institute of Technology have demonstrated that landmines generally exhibit mechanical resonances.

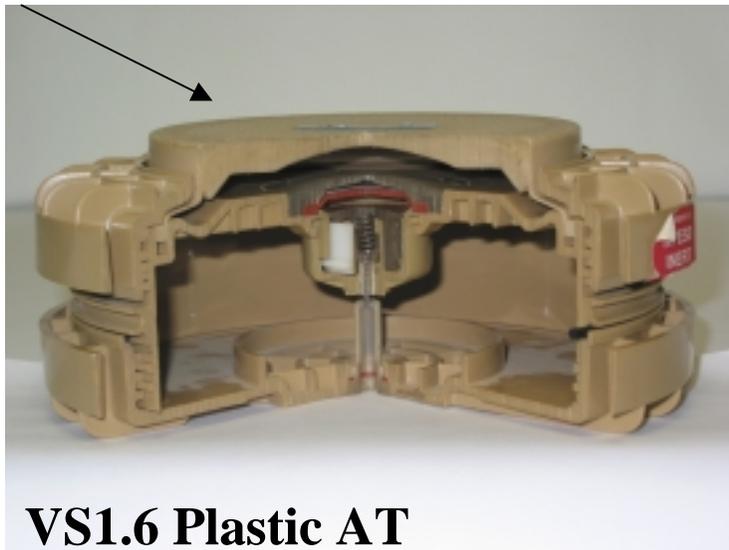


Phenomenology: Landmine Structural Resonances

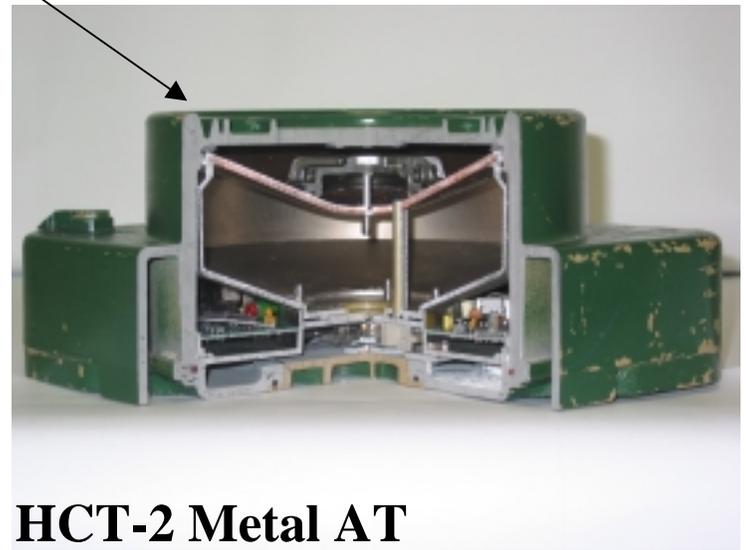


- The mechanical resonances exhibited by landmines are a function of mine casings and pressure plates.
- Landmine resonances usually correspond to rigid body motion of the mine pressure plate or the vibration modes of a clamped plate.

pressure plate



mine casing top plate



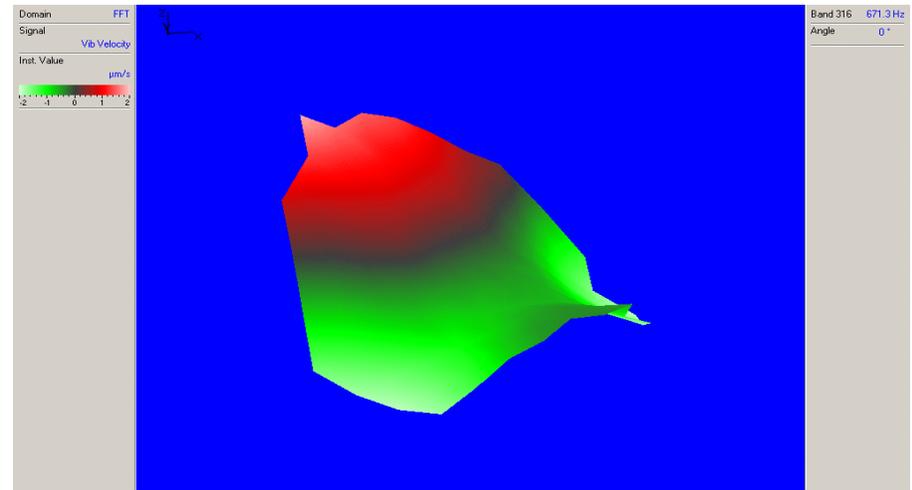
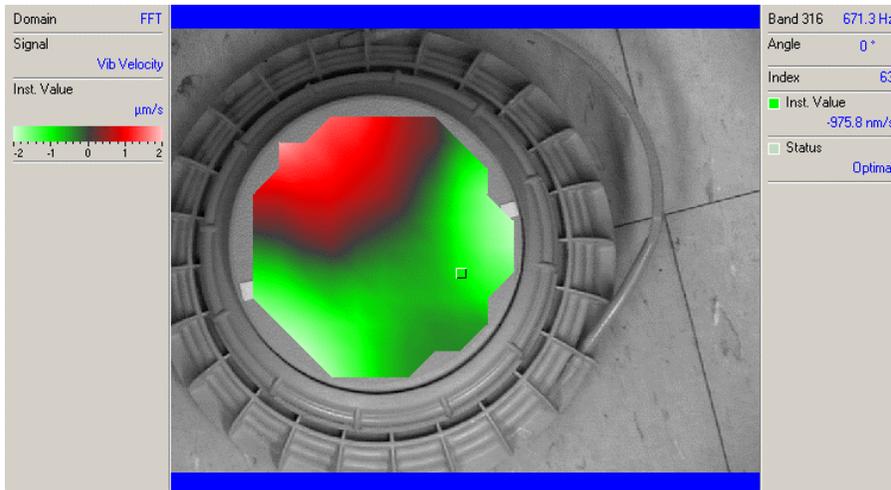
Phenomenology: Landmine Structural Resonances



VS2. 2 (Plastic AT) Mode Shapes

Animation of VS2.2 saddle mode at 671 Hz superimposed on VS2.2 image

Animation of VS2.2 saddle mode at 671 Hz



Experimental Findings: Stevens Institute of Technology



- Non-linear mine detection.
- Excitation: broadcast two frequencies f_1 and f_2 .
- Acoustic excitation couples into the soil causing the buried mine and the soil surrounding it to vibrate.
- Mine/soil interface theorized to be the source of non-linearity.
- Measure surface velocity at frequencies f_1+f_2 , f_2-f_1 , $2f_1-f_2$, and $2f_2-f_1$.

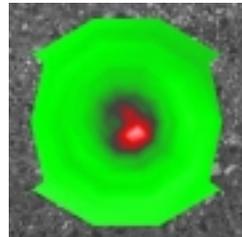
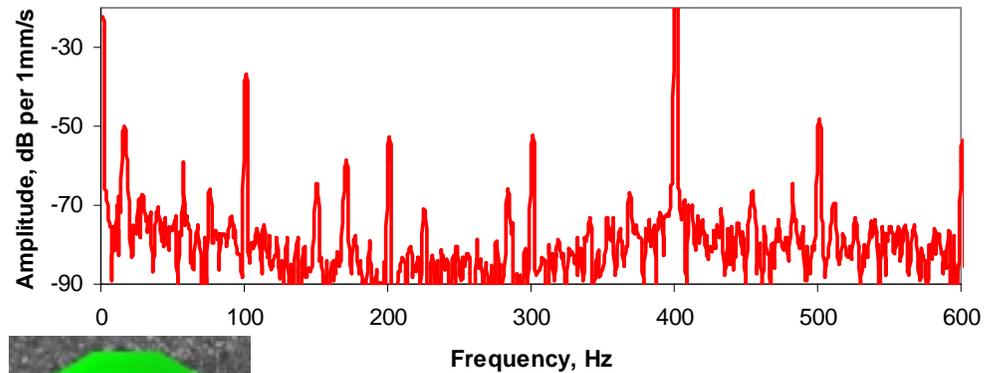


Experimental Findings: Stevens Institute of Technology

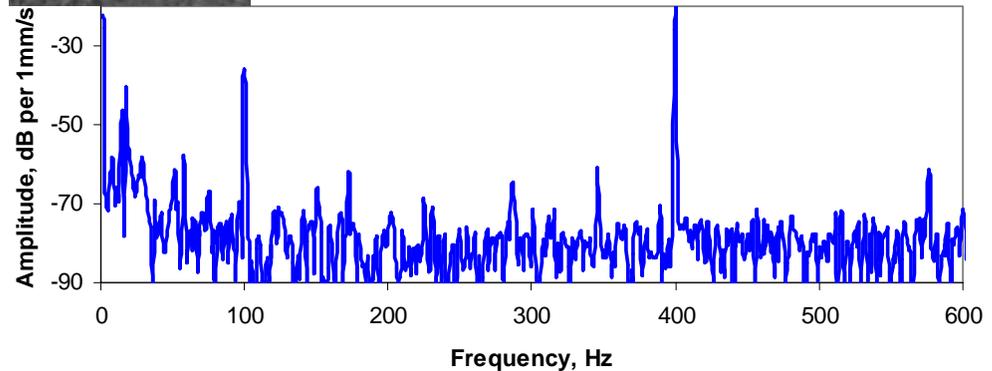


- Excitation: 100 Hz and 400 Hz tones.
- Lower plot illustrates on-target soil vibration
- Top plot illustrates off-target soil vibration.
- Frequency content at 300 Hz and 500 Hz (e.g. sum/difference frequency) is indicative of buried mine

GRAVEL LANE 19: **M14** @ 0.5"



GRAVEL LANE 19: **Offmine**

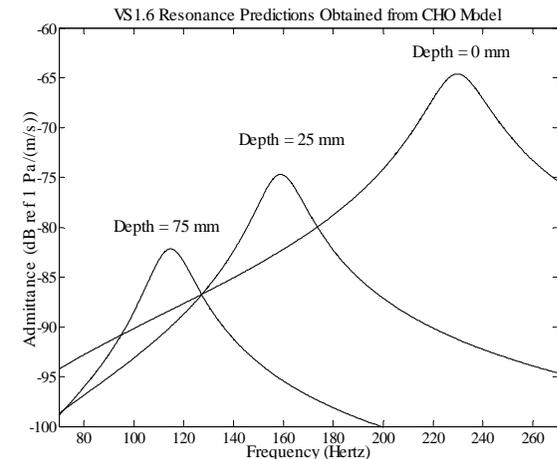
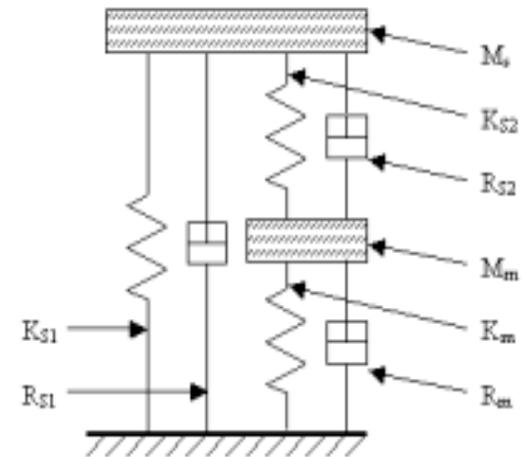


Modeling Efforts: Soil/Landmine Interface



Coupled Harmonic Oscillator Model

- Developed by Stevens Institute of Technology.
- Soil is modeled as right circular cylinder above mine.
- Dynamic mine parameters calculated from impedance measurements on free space mines.
- Dynamic soil parameters obtained from seismic/refraction survey.

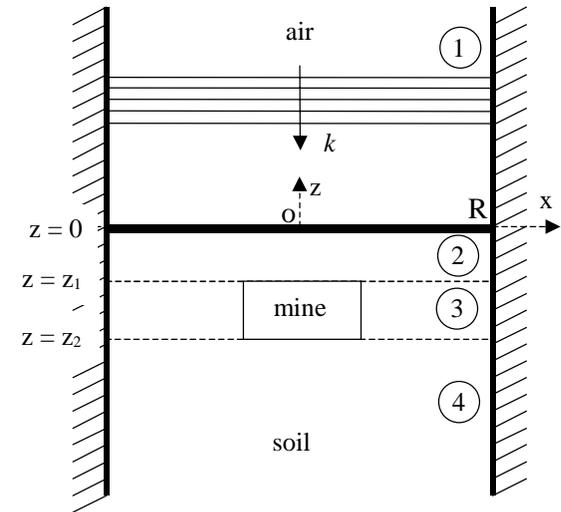


Modeling Efforts: Soil/Landmine Interface

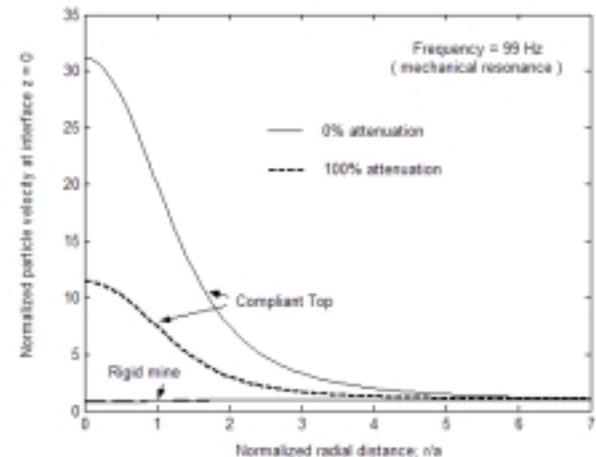


Acoustic Scattering Model

- Developed by University of Mississippi.
- Soil is modelled as an effective fluid or elastic solid.
- The mine is modelled as a simple harmonic oscillator
- Acoustic transmission problem.



There is a distinct need in the landmine detection community for the development of more complete analytical models of the soil/mine interface.



Additional Acoustics Research Efforts



- **Laser Confirmation Sensor**
NVESD/Carnegie Mellon Univ.
PSI/Metrolaser/Univ. Mississippi
- **Geophone Confirmation Sensor**
NVESD/Planning Systems (PSI)
- **Time Reversal Acoustics**
ARTANN Laboratories
- **Radar Doppler Vibrometer**
Technology Service Corp.
- **Acoustics/GPR Radar Fusion**
Univ. Mississippi/PSI
- **Multibeam Vibrometer**
Metrolaser/Univ. Mississippi
- **Ultrasonic Vibrometer**
NVESD
- **Ultrasonic Parametric Array**
NVESD

Specifications



- Acoustics is a promising technology for mine detection.
- Technology presently needs improvement in speed.
- Require .001 mm/s sensitivity at 100 Hz, better desirable.
- Require 7 cm. sample spacing on ground for antitank mines and 2 cm. spacing for antipersonnel mines.
- Require scanning rates of 1.0 m² in 20 sec. for a confirmation sensor.
- Require scanning rates of > 30 m²/s for a primary sensor
- Frequency range 50-1000 Hz

Countermine T&E Facilities



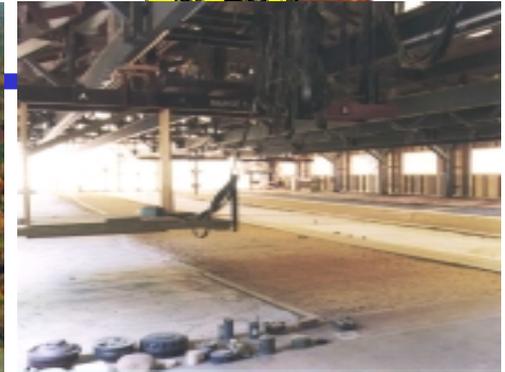
**S&T
Proving
Grounds**



**Demo Range
Vehicles and Handheld**



**Drop Zone
Overflight**



**Ft. Belvoir Mine Lanes
Sensor Evaluations**

**Acquisition
System
Performance
Testing**



Desert Site



Temperate Site

Prepared to Quickly Evaluate New Technology

Belvoir Mine Lanes



Countermine T&E Facilities

