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Covert Tunnel Detection Technologies

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1 Executive Summary

1.1 Subterranean Warfare Technologies

- Subterranean Warfare Technologies includes many different sciences and technologies (see the table below)
- Semi-autonomous detect & attack robots can navigate and map tunnels and provide explosives chemical readings and provide the operators with video data and more.
- Another published technology used to detect both tunnels and human beings inside the tunnel uses analysis of surface seismic waves generated by movement of persons, existence of human electromagnetic emissions in the EL band, and measurements of changes in the geomagnetic field.
- Pipeline research on electro-optic technology can be used as part of a border wall to locate tunnels.
- Each technology, including positive and false error rates, would be included in the transnational analysis. However, reliance on hard science and technology is not enough. For example, the DHS reported that initially the agency explored the possibility of an unmanned aircraft equipped with radar technology that would fly along the border searching for tunnels. However, the scientists and border agents both realized that most of the existing tunnels are concentrated in large urban centers where they are difficult to spot with satellite images.

Most traditional detection technologies are based on geophysical technology and they have had either little or no consistent or reliable success as a result of various limitations. The key technologies are shown below:

Table 1 - Subterranean Warfare Technologies: Advantages & Limitations

Technology	Advantages	Limitations
Ground Penetrating Radar (GPR)	▪ Low Cost ▪ Off the shelf technology ▪ Detects both active and silent tunnels	▪ GPR does not work well in moist mediums like clay or below the water table ▪ Depth limitation approximately 10-20 meter ▪ False alarms even at shallow depths are not uncommon ▪ Each system must be tailored to the local geology and eco-system
Passive Seismic	▪ Off the shelf technology ▪ Detects active tunnels ▪ Fast acquisition ▪ Good lateral and vertical resolution ▪ Can resolve very small anomalies ▪ Continuous profiling	▪ Requires real-time detectors ▪ Expensive ▪ Requires powerful imaging software – to filter out the waves' reactions to natural and man-made “noises” (e.g., highway traffic) ▪ Each system must be tailored to the local geology and eco-system
Electrical Resistivity Tomography	▪ Off the shelf technology ▪ Detects both active and silent tunnels ▪ Good Vertical and lateral resolution ▪ Simple interpretation	▪ Requires a wide-ranging network ▪ Needs to be permanently installed ▪ High Cost ▪ Each system must be tailored to the local geology and eco-system ▪ Interference from any conductor ▪ Not as effective in very conductive regions
Microgravity	▪ Detects both active and silent tunnels ▪ Passive technology ▪ Very accurate ▪ Interpretation can give depth, size and type of anomaly ▪ Can be used on any terrain	▪ Requires very high precision (the gravity differential for smuggling tunnels is >10 microgals, vs. the Earth's field of 800 gals) ▪ Expensive Technology ▪ Must be held at perfectly level at a constant temperature ▪ Each system must be tailored to the local geology and eco-system
Cosmic-Muon Detectors	▪ Detects both active and silent tunnels	▪ Requires a “fence” of Muon detectors ▪ Needs to be permanently installed ▪ Cost is developer dependent ▪ Each system must be tailored to the local geology

Technology	Advantages	Limitations
Electro- Magnetic	▪ Good lateral resolution ▪ Fast acquisition, no ground contact	▪ Limited vertical resolution ▪ Tough to use in urban environments
Magnetics	▪ Fast measurement ▪ Very sensitive to conductors ▪ Non-intrusive	▪ If no conductors is useless ▪ Sensitive to any surface conductor
Seismic Reflection/ Diffraction	▪ Gives information of depth and composition ▪ Good lateral resolution	▪ Sensitive to acoustic noise ▪ Extensive processing
Seismic Refraction	▪ Good lateral resolution ▪ Can resolve multiple layers	▪ Sensitive to acoustic noise ▪ Needs large spread lengths
Multichannel Analysis Of Surface Waves	▪ Not as sensitive to acoustic noise ▪ Fast acquisition	▪ Very Frequency dependent ▪ Low resolution
Borehole Seismic	▪ Gives ground truth ▪ Very accurate ▪ Limited processing	▪ Site needs boreholes ▪ Impracticable to drill at test sites
Fiber-Optic Cable	▪ Detects digging ▪ Low cost	▪ Does not detect silent tunnels ▪ Each system must be tailored to the local geology and eco-system
Fused Multi-Modal, Multi-Sensors System	▪ Low error rate ▪ Hard to defeat ▪ High 3D Resolution ▪ Detect passive and Active Tunnels, etc.	▪ High cost ▪ Each system should be tailored to the local geology and eco-system
Subterrain Detect & Attack Robots	▪ Stealth detection ▪ Can attack tunnels etc ▪ Subterranean Warfare game changer ▪ Force the rival to be use defensive measures ▪ Provide a symmetric sub terrain warfare	▪ Require RDT&E investments ▪ Need to adapt to local eco-system and rival tactics

1.2 Tunnels & Underground Structures Detection: Technological Requirements

1.2.1 Geophysical Information

Geophysical Analysis must be performed for each and every Tunnels & Underground Structures Detection project, Including:

- Depth of seismic sources
- Integrated infrasound (Low Frequency sound) and meteorological data
- Rapid computation, interpretation of local & regional synthetics
- Workflow optimized analytical environment
- Cross-domain data fusion (no single geophysical method is applicable everywhere)
  - Seismic (active and passive)
  - Acoustic, Infrasound
  - Electromagnetic Induction
  - Resistivity
  - Ground penetrating radar
- Local database of future sensor deployments

1.2.2 Geotechnical and other Challenges

Geophysical and other Challenges must be studied for each and every Tunnels & Underground Structures Detection project, Including:

- Local sub terrain material (e.g. clays, magnetite, salt)
- Local sub terrain faults, fractures, joints, bedding, paleo-channels
- Local groundwater level
- Local seismic velocity
- Local sub terrain ground conductivity
- Vegetative cover
- Terrain
- Rain
- Space available
- Urban structures
- Underground Utilities

- Utilities Power, Telephone, Cable
- Water, Sewer, Gas Utilities
- Overhead – Power lines
- Vehicle traffic
- Manmade Structures, Fences
- Animal life
- Self-interference & friendly fire

1.2.3 Key Geophysical Sensing Requirements

- Sensing in a non-lab environment
- Sensor networks
  - Common communications
  - Pre-processing on node prior to exploration
- Size and power matter
  - Trade-offs (minimize reduction in sensitivity or bandwidth)
- More robust and resilient sensors
  - No reduction in sensitivity (e.g. sensitivity locked until sensor is in place)
- Stability
  - Sensors that do not require frequent or lengthy calibrations
- No soaker hoses
  - Noise cancellation versus isolation
  - Advanced sensor concepts for noise reduction
- Common GPS time for all

More information can be found at:

Subterranean Warfare (Tunnels & Underground Structures Detection and Subterranean Robots) Technologies: Global Market – 2015-2020