Landmines and UXO

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An estimated 11 000 000 acres in the United States are potentially contaminated with unexploded ordnance (UXO). Cleanup of these UXO-contaminated lands is a high priority requirement for the Department of Defense (DOD). However, in spite of years of effort and an investment of hundreds of millions of dollars, an effective approach and efficient/reliable technology for detecting and/or mapping buried UXO remains largely unsolved. One explanation for the continued lack of solution of the UXO detection requirement is DOD's considerable history of lumping landmines and UXO together in their detection and remediation efforts. This grouping of landmines and UXO has led to unfocused, inefficient programs and has failed to produce a general purpose solution to either problem.

Definitions/scenarios. *Landmines* are a form of ordnance. However, landmines are placed on or under the ground (generally very shallow, < 10 cm) in an armed state and designed to explode in the as-placed condition upon encountering a triggering stimulus (e.g., pressure from foot or vehicular traffic or the magnetic or electromagnetic signature of nearby passing vehicles). *Mines are designed to be inherently unsafe in the as-placed condition.* Also, mines are frequently constructed with minimum metal content to avoid detection. Mines are circular or rectangular in cross-section and are generally placed with the largest dimensions parallel to the ground surface. Mines are sometimes laid in patterns or along transportation corridors or approach routes or along defensive positions. DOD's greatest requirement for landmine detection and clearance is at non-U.S. locations, where detection and clearance sometimes must be undertaken in the presence of external safety threats.

UXO are ordnance that are fired, launched or dropped and designed to detonate on impact with the ground, at the end of a preset time, or on proximity to a target. Their existence in a buried state in the ground means that they have malfunctioned — they are "duds." UXO were not designed to be buried in the ground in an unexploded state. UXO can exist at depths from the surface to 7-8 m. UXO have survived the extreme environments of being fired, launched, high-g impact, and penetration, although the safety status of the buried UXO cannot be stated with any assurance. However, *UXO are designed to be inherently safe* in a "stockpiled/unarmed" state, and casual handling will not cause detonation. Also, UXO are constructed of metal for strength and durability, with no thought ever of avoiding detection. UXO are almost always streamlined in shape and elongated in one dimension (an axis of symmetry). UXO are buried in virtually any orientation and generally randomly located in impact areas (i.e., no patterns). DOD's primary requirement for UXO detection and remediation is at training ranges and formerly used defense sites in the U.S. Detection and remediation can generally occur without external safety concerns.

Detection considerations. Ultimately, safe clearance of *landmines* requires a standoff or an unmanned, remote detection capability due to the inherently unsafe nature of landmines. Standoff detection capability can be achieved with both ground-based (booms) and airborne platforms. The fact that landmines exist from the surface to maximum depths of approximately 10 cm makes detection possible with various scanning/imaging geophysical systems, e.g., synthetic aperture radar (SAR), infrared (IR), multispectral "remote sensing", and scanning laser reflectance/polarization systems. Standard ground penetrating radar (GPR) and electromagnetic induction (EMI) also are applicable to mine detection. Since mines have very small metal content, magnetic survey systems have little applicability to their detection. It is only because of the very shallow burial of mines that SARs, IR and multispectral systems are applicable.

UXO does not in general require standoff detection capability. IR and multispectral imaging systems and SARs are not applicable to general purpose UXO detection. GPRs are not applicable to general purpose UXO detection due to the extremely site-specific depth of investigation capability and other special considerations. Since all UXO contain metals (generally ferrous), an integrated combination of magnetic and EMI systems is the preferred approach to UXO detection and mapping. In fact, magnetic surveying, which is not applicable to mine detection, is a primary tool for UXO detection. GPRs are applicable only to special purpose UXO discrimination and identification once the UXO has been located by other methods.

Conclusion. For purposes of military research and development, landmines and UXO are separate problems with different burial scenarios; ordnance operational scenarios; safety considerations; detection technology considerations; and remediation considerations. It follows that (1) detection and remediation of UXO and (2) detection and neutralization of landmines must be treated independently at all levels, or the DOD will continue to use scarce funding in pursuit of ill-advised joint landmine/UXO programs that fail to achieve workable solutions.

Due to the scope of the problem, UXO detection, mapping, and characterization are potentially large markets for geophysicists, geophysical equipment, and geophysical services. As long as the UXO detection and remediation requirement is grouped with the landmine detection and clearance (de-mining) requirement, the programs will likely be managed by the so-called "sensor development" community, and there will be little input by geophysicists to the planning, management, and execution of UXO detection programs. LE

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