

Small UAS-Deployable Ultra-Light Time-Domain Electromagnetic Induction Sensor

Max Orman-Kollmar¹

David Lozano²

Michele Maxson^{1,2}

Brian Quinn²

Benjamin Hoffer¹

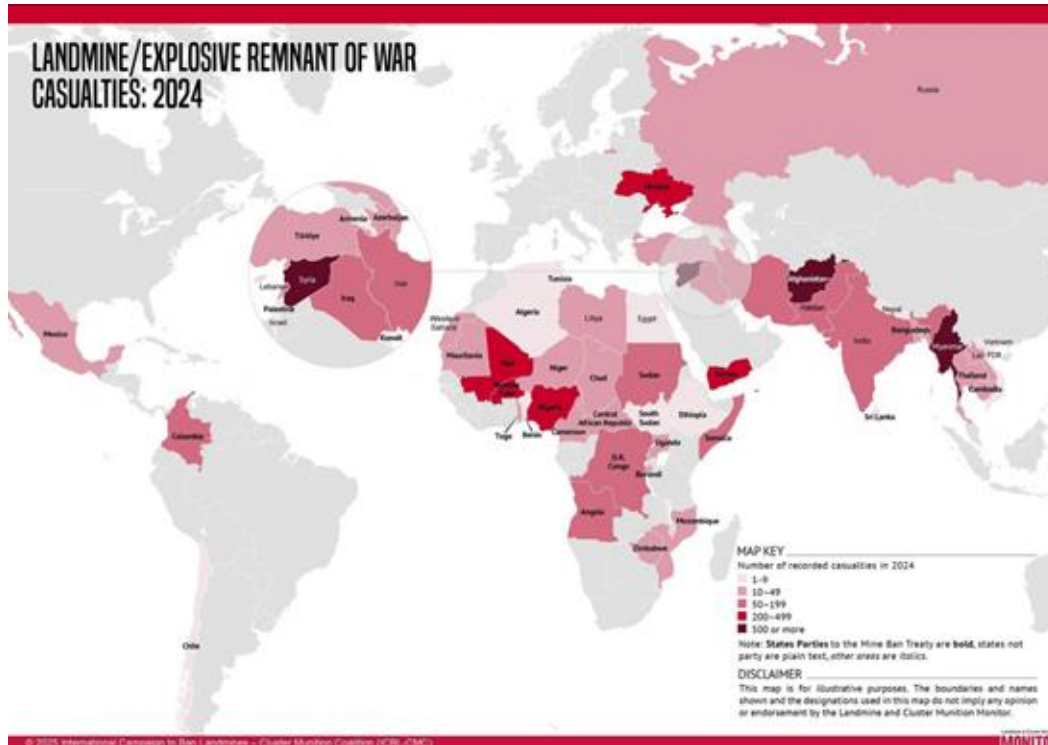
Fridon Shubitidze¹

¹Dartmouth College, Thayer School of Engineering

²US Army Engineering Research and Development Center (ERDC)

Background

- Prevalence of objects needed remote geophysical mapping, particularly unexploded ordnance (UXO)
- Number of estimated landmines/UXO/ Explosive Remnants of War (ERW) found worldwide
- Detect AND **classify**



APOPO HeroRats

Background

- Small but powerful unmanned aerial systems (UAS) afford faster and more stable surveys
- This allows for overall cheaper and more efficient surveys, whether looking for geological information or BEH and UXO



Geometrics
MagArrow



(a)



(b)

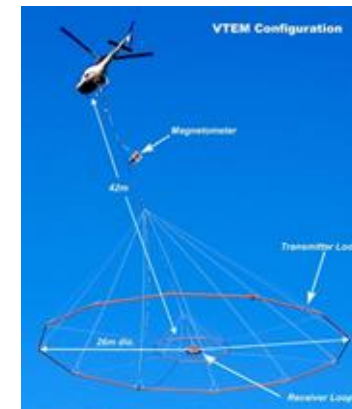
UAS-mounted sensors for UXO detection (left) and soil conductivity detection (right)
“Analysis of the Feasibility of UAS-Based EMI Sensing for Underground Utilities Detection and Mapping”, Hartshorn et al

State of Time-Domain EMI

- Time-Domain Electromagnetic Induction (TDEMI) is a widely accepted and proven modality for UXO detection and classification
- However, commercially available systems often exceed 100 lbs, making them unsuitable for UAS-deployment
- TDEMI surveys done from air usually require a helicopter to tow the array, which is slow and prohibitive



Land-Based
TDEMI Platform



Helicopter TDEMI Survey
"Helicopter Electromagnetic (VTEM
and ZTEM) Applications for Gold
Exploration", Legault et al

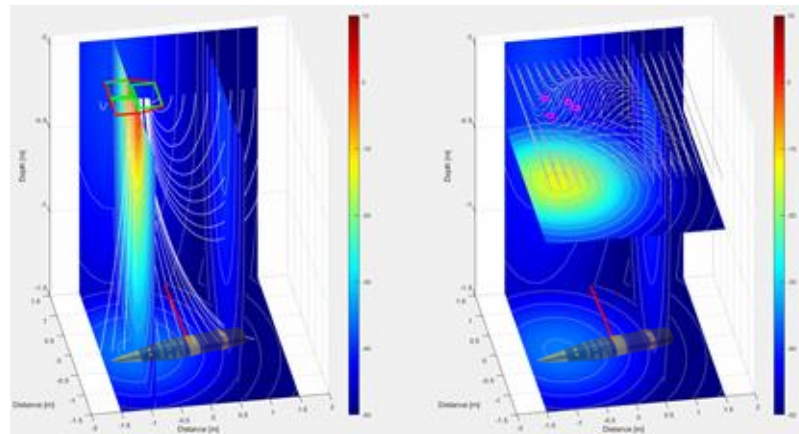
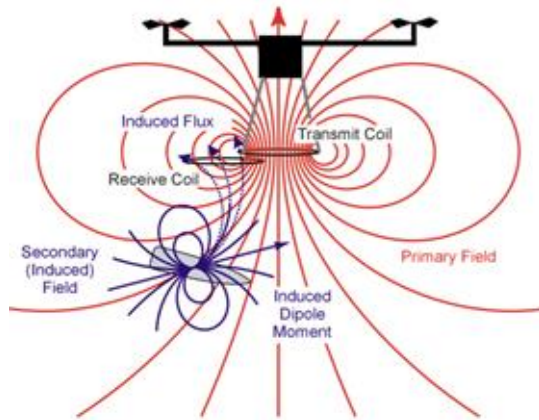
Ultra Lightweight Electromagnetic Array

- EMSG at Dartmouth College has developed the Ultra Lightweight Electromagnetic Array (ULEMA), a lightweight multimodal TDEMI sensor for deployment on variable autonomous platforms



Time-Domain Electromagnetic Induction

- Active transmitter generates a primary magnetic field through pulsed current
- Time-varying primary field leads to induced secondary magnetic field from conducting objects
- Secondary field is sensed by passive receivers
- Induced field response is a function of target shape, size, and material



Primary Field-
Transmitter

Secondary
Field- Receiver

System Description

- 31" x 31" footprint
- ~16 lb total payload weight
- Independent GPS/IMU solution
- Four active transmitters
- Four triaxial receivers
- Real-time data visualization and processing



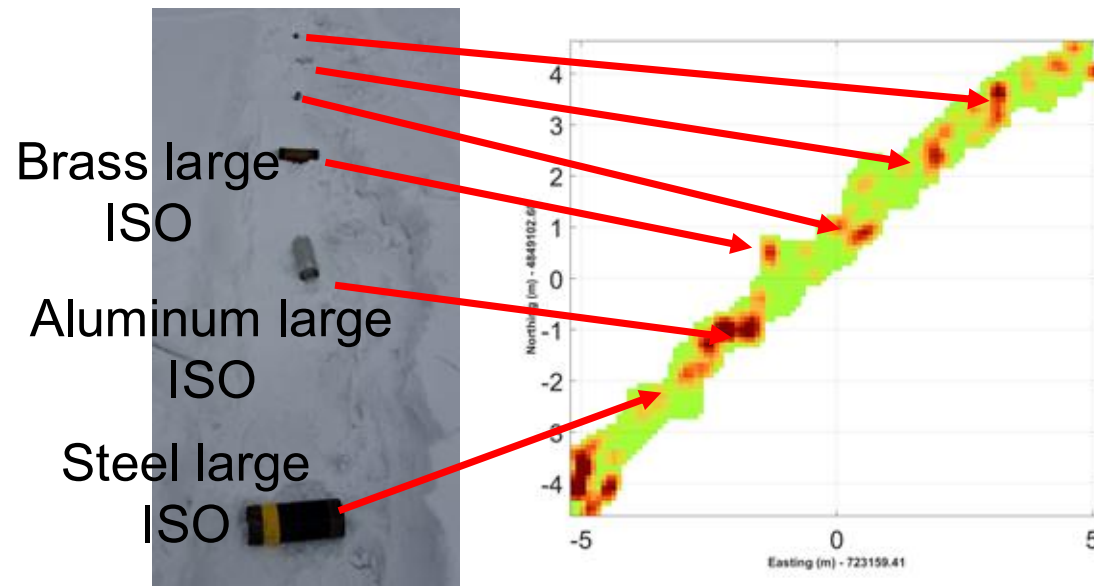
UAS Mounting and Deployment

- ~0.5 m/sec travel speed (for data every 10cm)
- ~40 cm lane sizes
- Suspended below UAS with ~10 ft (3 m) tethers, allowing for safe take off and landing
- Flown with both programmed and manual missions
- altimeter mounted below array to control for distance



Data Collections

- Six Industry Standard Object (ISO) targets laid out
 - Three medium (8" long, 2.375" outer diameter), three large (12" long, 4.5" outer diameter) of steel, aluminum, and brass, laid horizontally in 8" deep channel
- Direct flight path programmed over the targets
- Detection map shows the targets being clearly picked up



Classification Run

- Lay out targets with known GPS points
- Data collection run over line of targets



Classification and Localization

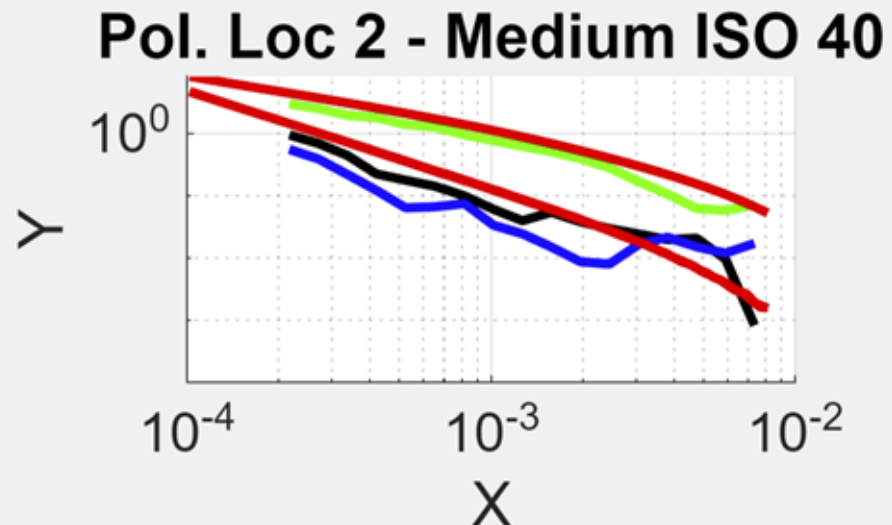
- Lay out targets with known GPS points
- Data collection run over line of targets



Classification and Localization

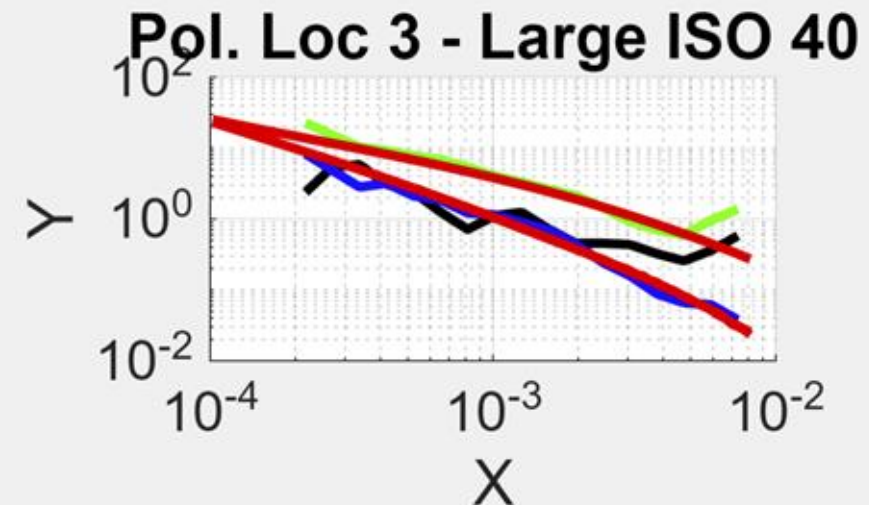
Location 2			
GrTr. Pos 2	0	0	-53 [cm]
Pred. Pos 2	7.79	-0.12	-46.56 [cm]
Error: Pos 2	-7.79	0.12	-6.44 [cm]

Location2 Target Medium ISO 40



Location 3			
GrTr. Pos 3	0	-20	-70 [cm]
Pred. Pos 3	0.29	-20.99	-78.02 [cm]
Error: Pos 3	-0.29	0.99	8.02 [cm]

Location3 Target Large ISO 40



Further Work

- Integration stability improvements
- More surveys done
- More flight modes (ascent/descent in addition to dynamic lines and cued collects)
- Addition of brass and aluminum targets to library

Thank you!

Contact Information:

Benjamin.A.Hoffer@dartmouth.edu

MaxOrmanKollmar.TH@dartmouth.edu