

Introduction:

The bounds of an AGC sensor system's depth of detection and depth of reliable classification of a given TOI have been an open question since the inception of AGC and the fielding of the foundational sensor systems that brought the methodology into existence. The recently signed-out DoD QSR v3.0 and supporting DAGCAP SOPs codified this need into an upcoming requirement for AGC hardware vendors to address individually.

Methodology:

Temsense LLC has developed a workflow to evaluate the operational depth ranges for a given TOI using the DAGCAP-validated Temsense system. Known intrinsic properties of the TOI are synthetically seeded into segments of real-world, anomaly-free background data over the range of reasonable extrinsic seed parameters such as depth, azimuth angle, dip angle, and the footprint of the array.

- **Detection is based on the criterion that the monostatic, z-axis signal exceeds five times (5x) the RMS noise level at a time gate centered on 0.137 ms.**
- **Classification is based on the criterion that the polarizabilities estimated from signal plus noise data match the corresponding library polarizabilities with a standard library match metric value of at least 0.825. The performance of this criterion is also compared to that of signal exceedance of ten times (10x) the RMS noise level.**

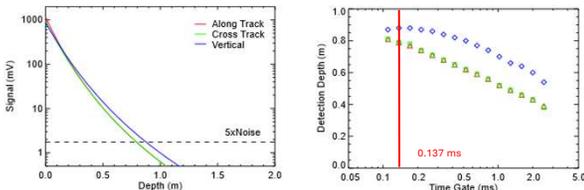
Reliable Detection Depth:

- Response curves were calculated for three orientations:
 - along track, cross track and vertical (nose down)
- RMS noise levels for stretches of anomaly-free survey data
- Early time gates are more favorable for detection because signal amplitudes generally decay faster with time than the noise does

Peaks with an SNR ≥ 5 are detectable to depths of ≥ 10 munition diameters, in keeping with the empirical USACoE "11x rule"

Target	Along Track (m)			Cross Track (m)			Vertical (m)			Diameters avg, med
	min	med	max	min	med	max	min	med	max	
37mm	0.42	0.48	0.50	0.43	0.48	0.50	0.45	0.52	0.54	13.3
SISO	0.39	0.45	0.47	0.42	0.45	0.47	0.48	0.57	0.59	14.7
60mm	0.66	0.72	0.73	0.68	0.72	0.73	0.71	0.77	0.79	12.3
MISO	0.73	0.79	0.81	0.75	0.79	0.81	0.80	0.87	0.89	13.6
105mm	1.07	1.11	1.13	1.07	1.11	1.13	1.01	1.05	1.07	10.4
LISO	1.12	1.16	1.18	1.12	1.16	1.18	1.06	1.11	1.13	10.0
155mm	1.31	1.35	1.36	1.31	1.35	1.36	1.12	1.16	1.17	8.3

MISO (0.137ms)



Targets of Interest:

A range of TOI sizes evaluated:

- 37mm 37mm projectile AP-T M74
- 60mm 60mm mortar M49A5
- 105mm 105mm projectile M1
- 155mm 155mm projectile M107
- SISO Schedule 80 small ISO
- MISO Schedule 80 medium ISO
- LISO Schedule 80 large ISO



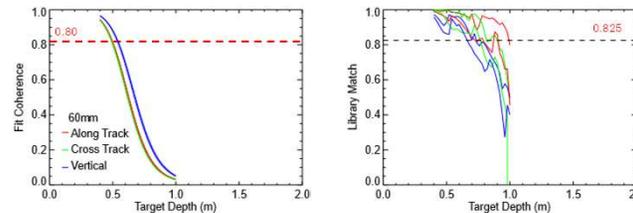
Dynamic Classification Depth:

Inversion results calculated for synthetically seeded TOI, three orientations:

- Along track, cross track and vertical (nose down)
- For single passes (RI transects), and multi-pass (lawn-mower) surveys

Reliable classification depths based on a library match threshold of 0.825 are shown for single and multi-pass inversion.

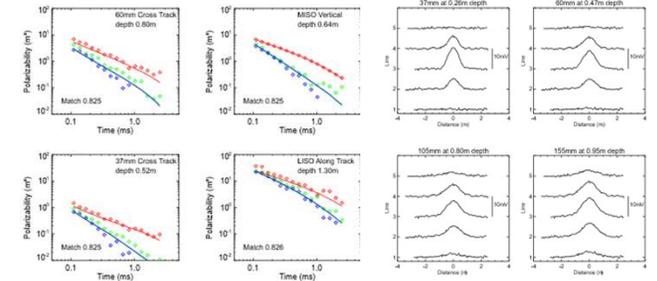
- Multi-pass inversion improves performance the most for the larger, deeper targets.
- The library match-based metric is derived from the standard UX-Analyze AGC workflow.
- Accurately reflects how an AGC job is typically conducted.
- The SNR $\geq 10x$ criterion appears to be a reasonable surrogate for single pass transects but appears overly conservative for the deeper targets and multi-pass inversion.
- Multi-pass inversion the 0.825 library match criterion yields detection depths which average about 30% deeper than corresponding 10x classification depths.
- Multi-pass inversion (left) and classification (right) results for the 60mm mortar.



Target	Inversion	Along Track (m)			Cross Track (m)			Vertical (m)			Diameters avg, med
		min	med	max	min	med	max	min	med	max	
37mm	Single Pass	0.48	0.54	0.54	0.4	0.42	0.56	0.32	0.34	0.34	11.7
	Multi Pass	0.57	0.63	0.66	0.49	0.53	0.61	0.34	0.39	0.59	14.0
SISO	Single Pass	0.46	0.49	0.5	0.3	0.47	0.53	0.24	0.25	0.25	12.1
	Multi Pass	0.5	0.55	0.58	0.4	0.44	0.54	0.25	0.43	0.49	14.2
60mm	Single Pass	0.56	0.58	0.58	0.64	0.67	0.8	0.6	0.63	0.63	10.4
	Multi Pass	0.73	0.92	0.99	0.77	0.8	0.82	0.66	0.67	0.73	13.3
MISO	Single Pass	0.58	0.61	0.84	0.68	0.71	0.83	0.54	0.56	0.78	10.4
	Multi Pass	0.83	1.05	1.07	0.78	0.84	0.87	0.59	0.62	0.66	13.9
105mm	Single Pass	0.94	0.94	0.95	1.06	1.09	1.16	0.68	0.69	0.69	8.6
	Multi Pass	1.22	1.26	1.39	1.33	1.42	1.43	1.02	1.06	1.34	11.9
LISO	Single Pass	0.99	0.99	0.99	1.14	1.17	1.18	0.91	0.92	0.92	9.0
	Multi Pass	1.3	1.31	1.36	1.34	1.44	1.47	1.06	1.09	1.2	11.2
155mm	Single Pass	1.2	1.21	1.21	1.3	1.31	1.31	1.1	1.11	1.12	7.8
	Multi Pass	1.51	1.53	1.55	1.58	1.59	1.6	1.22	1.22	1.24	9.3

Examples of estimated and library polarizabilities at the 0.825 threshold.

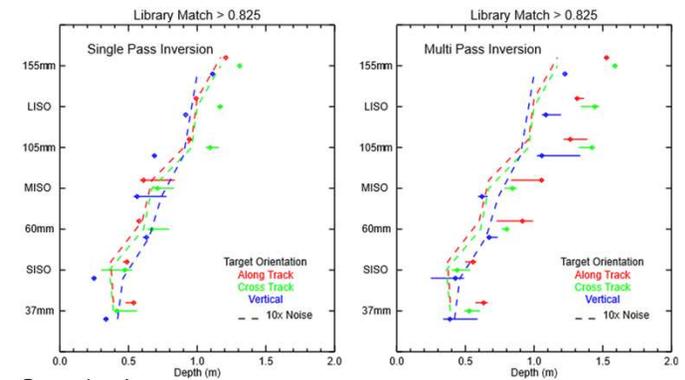
Would a rational data analyst declare all four "TOI"?



Examples of calculated data chips at 0.137 ms with SNR ≈ 30

Larger, denser data chips yield better fits, but lower fit coherence

Depth is that at which the library match drops below 0.825 for the first time in our simulations. The horizontal lines run from the minimum to the maximum in the target location window, with the symbols plotted at the median.



Conclusions:

Reliable depths of detection, and importantly, the range of possible values, are presented for a typical range of TOI. TOI detection is robust at an SNR ≥ 5 . Classification is robust for library match metrics of ≥ 0.825 . Using a threshold of an SNR ≥ 10 for classification also works well for smaller, shallower items, but appears to be overly conservative for larger, deeper items. Site-specific variations (i.e., geology, noise floor) will also impact depth performance and should be evaluated on a case-by-case basis.

These results can help guide a project team to make informed decisions about project goals and metrics at all stages of the remediation process.

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