MESAS 2026
Modelling and Simulation for Autonomous Systems

Options for Protecting Personnel and Artillery Equipment from Observation and Attacks by Unmanned Aerial Vehicles

Ondřej Pekař[1], Jan Pištělák[2], David Homolka[1], Miroslav Mušinka[3], Vlastimil Šlouf[1]

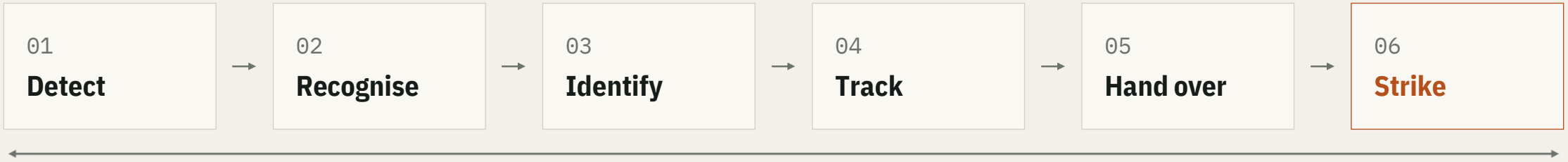
[1] Department of Fire Support, Faculty of Military Leadership, University of Defence, Brno, Czech Republic

[2] RETIA, a.s., Pardubice, Czech Republic

[3] Department of Military Tactics and Operational Art, Armed Forces Academy of General Milan Rastislav Štefánik, Liptovský Mikuláš, Slovakia



UAVs compress the reconnaissance–strike cycle



Time from discovery of a target to delivery of effects, shortened by the availability and sensor capability of UAVs

PASSIVE MEASURES

Reduce detectability, complicate recognition, distort the adversary's assessment, limit the consequences of an attack.

ACTIVE MEASURES

Detect, track and identify the UAV; disrupt it electronically (soft-kill) or engage it physically (hard-kill).

Protection must interrupt the cycle at several points, not only at the final attack.

01 · CONTEXT

An artillery battery is exposed in three signature domains

OPTICAL	INFRARED	RADIO-FREQUENCY
Vehicle size and silhouette, exposed personnel, disturbed vegetation, tracks, recurring activity patterns	Engines and exhaust systems, recently fired weapons, heat accumulated by equipment	Voice and data communications, navigation systems and other command-and-control emitters

EXPOSURE PERIODS	Occupying or leaving firing positions · ammunition resupply · personnel outside protected vehicles
UAV THREATS	Reconnaissance UAVs · attack UAVs · loitering munitions and FPV systems · UAVs with EW payloads

The threat is cumulative: persistent observation correlates single indicators over time into a picture of the battery's location and activity.

The study looks for a practicable mix of passive and active measures

OBJECTIVE

Identify a practicable combination of passive and active measures that reduces the probability of observation and enables an effective response to UAV threats at battery level.

SCOPE

- Firing battery: CAESAR self-propelled howitzers, mobile fire direction centre (FDC)
- Protected: personnel, howitzers, ammunition vehicles, FDC
- Procurement and life-cycle costs not quantified

APPROACH

01 Threat and protection framework

02 Three protection variants

03 Six criteria; Fuller and Saaty weights

04 TOPSIS ranking

05 Simulation in the Higher-Level Demonstrator

06 Sensitivity of the ranking

07 Integrated protection concept

02 · PROTECTION VARIANTS

Three variants combine passive and active measures differently

VARIANT A

Predominantly passive protection

Signature reduction and deception; only emergency fire from personal and vehicle weapons.

- Multispectral camouflage
- Decoys with heat sources, tracks
- Dispersion, several waiting areas
- Varied routes and logistic points
- Emission, light, noise discipline

0 added personnel

0 added vehicles

VARIANT B

Organic counter-UAS capability

Passive baseline plus an organic element that detects, assesses, disrupts and engages.

- Short-range radar
- RF detection and jamming
- Two mobile engagement teams
- Interceptor UAVs, portable jammers
- C-UAS coordinator at the FDC

+13 added personnel

+4 added vehicles

VARIANT C

Air-defence reinforcement

Passive baseline plus an externally assigned air-defence element; its vehicles stay external.

- ReVisor sensor, range up to 25 km
- Air-defence effectors
- AD commander at the battery FDC
- Portable jammers at battery level
- Depends on an available AD unit

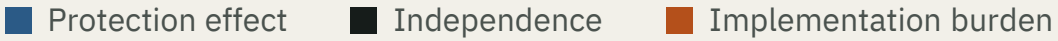
+2 added personnel

0 added vehicles

03 · MULTI-CRITERIA EVALUATION

Six weighted criteria balance protection effect against burden

CRITERION	SYMBOL	MEASURE	AIM	WEIGHT
C-UAS response effectiveness	SP	score 0–100	max	0.327
Ability to reduce detectability	ZO	score 0–100	max	0.278
Independence from external capabilities	Z	binary 1 / 0	max	0.161
Command-and-control complexity	NC2	new C2 elements	min	0.112
Personnel requirements	PN	added personnel	min	0.074
Material and technical requirements	MN	added vehicles	min	0.050



Weights are the mean of Fuller’s and Saaty’s pairwise comparison methods, normalised to 1. SP and ZO are composite scores based on the literature and the authors’ expert judgement.

TOPSIS ranks the variants by closeness to the ideal solution

DECISION MATRIX	SP max	ZO max	Z max	NC2 min	PN min	MN min
WEIGHT	0.327	0.278	0.161	0.112	0.074	0.050
Variant A	9.125	86.100	1	0	0	0
Variant B	75.000	43.225	1	1	13	4
Variant C	89.900	43.225	0	1	2	0

PROCEDURE

01 Normalise the criterion values → 02 Apply the criterion weights → 03 Find ideal and basal values → 04 Euclidean distance to each →

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

03 · MULTI-CRITERIA EVALUATION

Variant C ranks first, Variant B a close second

RANK 1 · VARIANT C

0.571

D+ 0.179 · D− 0.238

Highest C-UAS effectiveness with a small direct personnel burden; reduced by dependence on external air defence.

RANK 2 · VARIANT B

0.561

D+ 0.169 · D− 0.215

Closest to the ideal solution, but 13 personnel, 4 vehicles and a new C2 element lower the overall result.

RANK 3 · VARIANT A

0.470

D+ 0.225 · D− 0.199

Lowest burden and best concealment cannot compensate for missing early warning and active engagement.

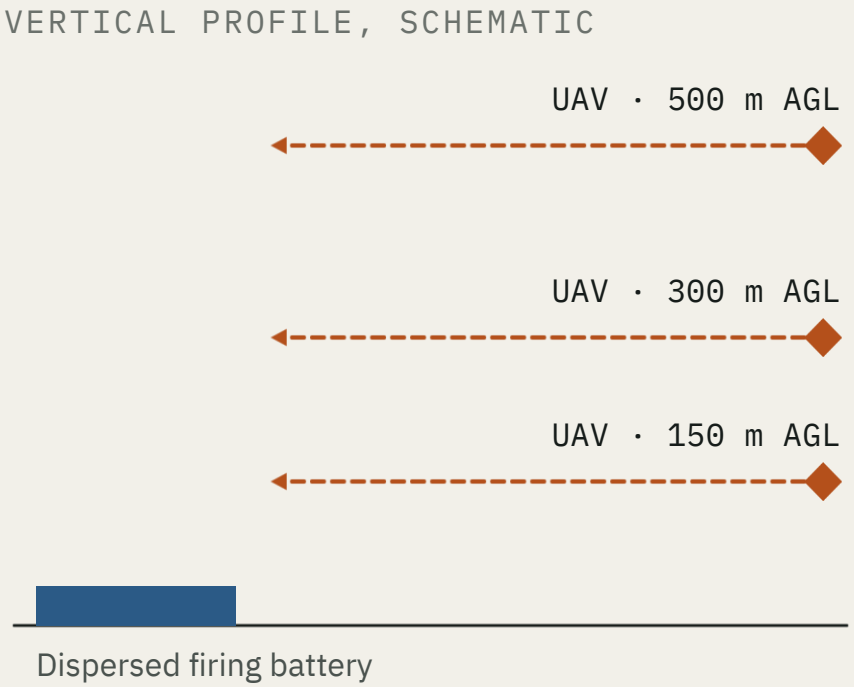
RELATIVE CLOSENESS TO THE IDEAL SOLUTION · AXIS FROM 0.45



04 · SIMULATION

All variants are simulated in the same tactical scenario

TOOL	Higher-Level Demonstrator, a hardware-software tool for comparing courses of action
AREA	South-east of Vyškov, between Lhota, Pačlavice and Dětkovice
THREAT	Three reconnaissance UAVs on predefined routes at constant heights
BATTERY	Dispersed; common baseline of optical camouflage and natural materials
COMPARED	Early detection, disruption or elimination, keeping UAVs out of the firing-position area



Comparative demonstration, not a prediction of combat outcomes.

Variant A: the UAVs complete their reconnaissance



Fig. 1 · Higher-Level Demonstrator, Variant A

CONFIGURATION

Passive baseline only: no sensor for early warning, no active system

OUTCOME

Reconnaissance completed

All three UAVs followed their planned routes, flew over the firing-position area and completed reconnaissance without disruption.

OBSERVATION

Once a UAV has entered the area, passive measures alone cannot prevent persistent search.

04 · SIMULATION

Variant B: the UAVs are detected and disrupted



Fig. 2 · Higher-Level Demonstrator, Variant B

CONFIGURATION

ReVisor surveillance sensor and an electronic-warfare system

OUTCOME

Detected and disrupted

The UAVs were detected and localised at sufficient distance; their activity was disrupted before they reached the firing positions.

OBSERVATION

Gain: spatial and temporal warning. Gap: no long-range hard-kill means against UAVs that resist or bypass EW.

Variant C: the UAVs are detected and eliminated

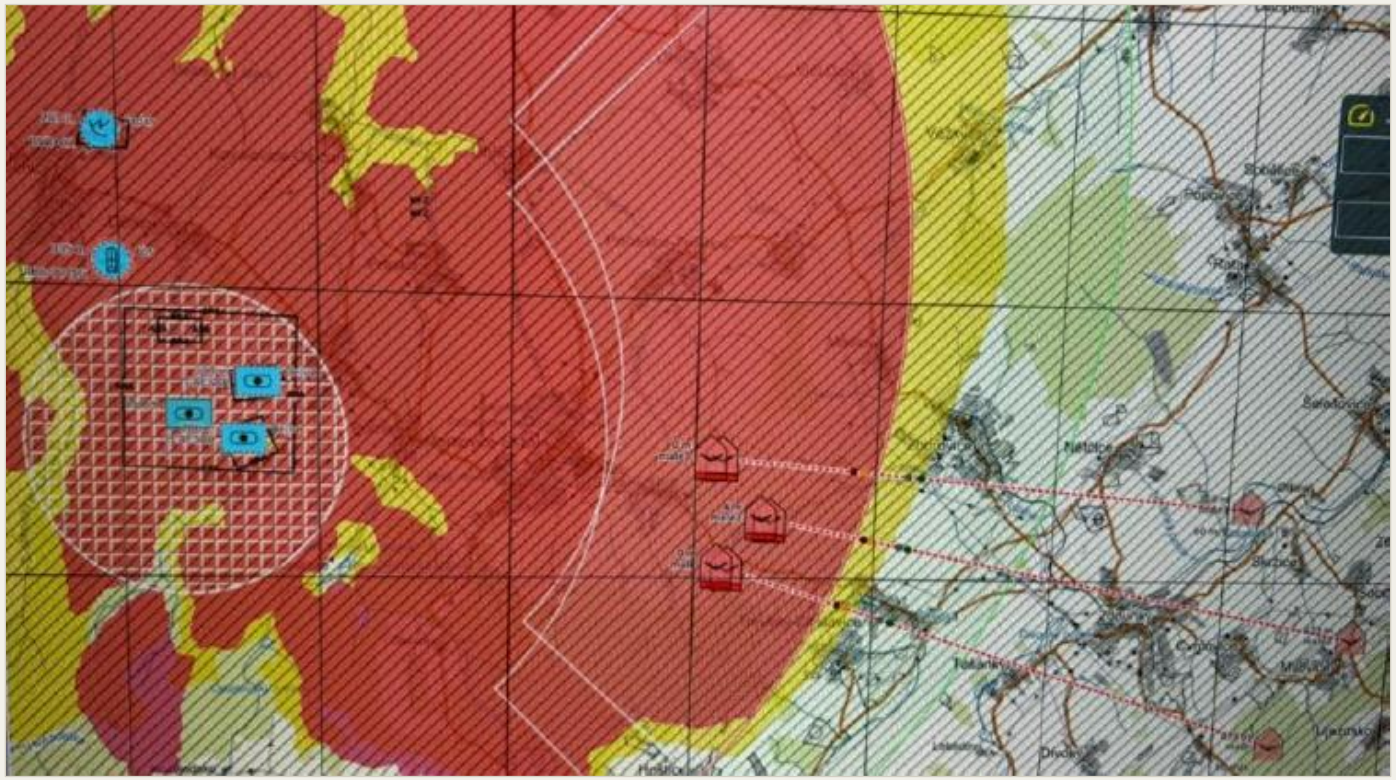


Fig. 3 · Higher-Level Demonstrator, Variant C

CONFIGURATION

Reinforcing air-defence element: ReVisor sensor with RBS-70 NG effectors

OUTCOME

Detected and eliminated

All three UAVs were detected and eliminated before they could operate effectively against the battery.

OBSERVATION

Terrain reduced the actual coverage below the nominal maximum ranges; sensor and effector placement matters.

The order of Variants B and C depends on the weights

ONE WEIGHT AT A TIME

1.06× **Independence from external capabilities**

Weight 0.161 raised to 0.169: Variant B overtakes C

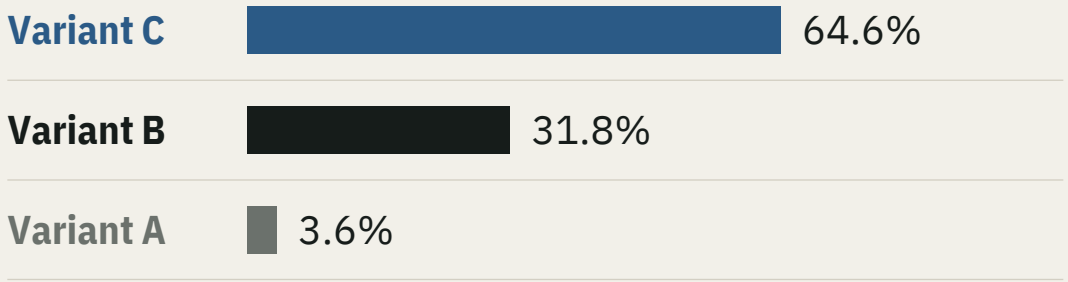
1.96× **Command-and-control complexity**

Weight 0.112 raised to 0.198: Variant B overtakes C

Other four criteria: no reversal for multipliers between 0 and 3. No single weight reduction changes the leader.

ALL WEIGHTS ×0.8–1.2 AT ONCE · 20,000 RUNS

Share of runs in which each variant ranks first



Variants B and C should be treated as jointly preferred. Choosing between them is a command judgement about the availability of air-defence support, not a property of the variants.

KEY FINDING

Passive measures alone do not provide sufficient protection. Timely detection and immediate response are decisive.

The results support a three-layer protection system

LAYER 3 **Situation-dependent reinforcement** from Variant C	Mobile air-surveillance sensors and air-defence effectors, integrated into the battery's C2 process, movement plan, airspace control and training cycle.	APPLIED Priority target, intense UAV threat or high-priority task
LAYER 2 **Organic active capability** from Variant B	Minimum: warning, immediate-reaction procedures, portable EW and a coordination function at the FDC. Full: organic sensor, EW element and mobile engagement teams.	APPLIED Core of active protection, scaled to mission and resources
LAYER 1 **Permanent passive protection** from Variant A	Multispectral camouflage, credible deception, emission discipline, dispersion and manoeuvre, alternate positions, varied routes, protected logistics.	APPLIED Always, across the whole battery

ACROSS ALL LAYERS

Command and control

Warning, response authority, effector assignment and airspace control, coordinated through the battery fire direction centre.

The results rest on expert scoring and a simplified scenario

LIMITATIONS

- Composite scores from the literature and the authors' expert judgement, not from field trials
- Costs, ammunition, interoperability, survivability and legal constraints not included
- Simplified scenario: predefined routes and altitudes, only effects available in the HLD
- Order of B and C not robust to the weights

FURTHER WORK

- Re-elicit criteria and weights with artillery, air-defence and EW specialists; repeat the sensitivity analysis
- Field exercises: autonomous UAVs, fibre-optic FPV, coordinated attacks, decoys, degraded communications
- Heuristic optimisation, e.g. ant colony, for protection planning under multiple constraints

Disclosure: one co-author is employed by the manufacturer of the ReVisor sensor. This author provided the sensor specification only and took no part in scoring, weighting or the TOPSIS evaluation.

Conclusions

1 Passive protection is the indispensable foundation, but on its own it cannot stop persistent reconnaissance once a UAV enters the area (Variant A, 0.470).

2 Early detection and immediate reaction are decisive. Variants C (0.571) and B (0.561) are jointly preferred; which one leads depends on the availability of air-defence support.

3 Recommended: three layers — permanent passive protection, an organic core of warning, EW and close engagement coordinated at the FDC, and air-defence reinforcement for high-threat or priority missions.

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Thank you

Questions and discussion

[Michal Švehlík] · [michal.svehlik@unob.cz]

University of Defence, Brno · RETIA, a.s., Pardubice · Armed Forces Academy, Liptovský Mikuláš



BACKUP

Detailed comparison of the protection variants

	Variant A	Variant B	Variant C
DETECTION	Visual observation and external warning	Organic short-range radar and RF/EW detection	Air-defence surveillance sensor and local air picture
SOFT-KILL	None beyond available vehicle systems	Vehicle-mounted and portable EW systems	Portable jammers at battery level; external element as available
HARD-KILL	Personal and vehicle weapons in immediate defence	Two mobile engagement teams and interceptor UAVs	Air-defence effectors supported by surveillance and C2
ADVANTAGE	Lowest implementation burden and strongest deception concept	Autonomous and layered response at battery level	Highest active protection and engagement at greater distance
LIMITATION	Very limited ability to react after UAV detection	High personnel, material, training and coordination burden	Dependence on an externally assigned air-defence element

BACKUP

Sensitivity of the ranking to single criterion weights

CRITERION	WEIGHT	REVERSAL MULTIPLIER	WEIGHT AT REVERSAL	NEW LEADER
C-UAS response effectiveness (SP)	0.327	none in 0–3	—	—
Ability to reduce detectability (ZO)	0.278	none in 0–3	—	—
Independence from external capabilities (Z)	0.161	**1.06**	**0.169**	**B**
Command-and-control complexity (NC2)	0.112	**1.96**	**0.198**	**B**
Personnel requirements (PN)	0.074	none in 0–3	—	—
Material and technical requirements (MN)	0.050	none in 0–3	—	—

Simultaneous perturbation of all weights by a factor from 0.8 to 1.2, renormalised, 20,000 runs: C leads in 64.6%, B in 31.8%, A in 3.6% of runs.

Reversal multiplier: the factor by which a single weight must be scaled, with the others rescaled proportionally, for the leading variant to change.

BACKUP

Definition of the composite criteria and the weighting

SP · SCORE 0–100

C-UAS response effectiveness

- Early detection
- Identification and threat assessment
- Electronic disruption
- Physical engagement
- Response to repeated or multiple UAVs

ZO · SCORE 0–100

Ability to reduce detectability

- Camouflage
- Deception
- Emission discipline
- Dispersion

WEIGHTS

Two pairwise methods

- Fuller: preference counts
- Saaty: intensity of preference, reciprocal matrix
- Final weight: mean of both, normalised to 1

Composite scores reflect the literature review and the collective expert judgement of the authors.