



Simulation-Ready AI- Orchestrated Multi-Layer Autonomous Framework for Critical Infrastructure Protection

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Heterogeneous Sensors



Radar



EO/IR



Thermal



Acoustic



RF

Autonomous Assets



UAVs



UGVs

Human Decision-Makers



Supervision



Authority



Intervention

Dynamic Threats



Personnel



Vehicles



Drones



Multiple Events

From Platform-Level Autonomy to Mission-Level Orchestration

CURRENT RESEARCH

Individual Capabilities

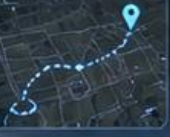
Sensor fusion



UAV reconnaissance



UGV navigation



AI detection



Human-AI interaction



PROPOSED APPROACH

Integrated Orchestration



Research gap: Limited integration across the complete mission lifecycle.

Research Design: From Literature to a Formal Model

1

Literature and M&S Research



- Critical infrastructure protection
- Autonomous systems (UAV/UGV)
- AI decision support
- Human-AI teaming
- Modelling and simulation

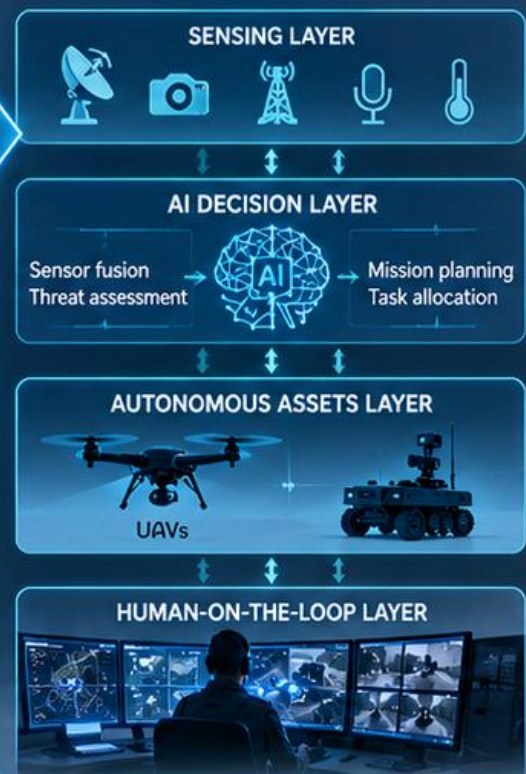
2

Operational Requirements



3

AI-OMMF Architecture



4

Operational Decision Model

$$\text{ODM} = (S, E, A, C, D, O, \delta)$$

- S** Operational states
- E** Events
- A** Available assets
- C** Operational constraints
- D** AI decision function
- O** Mission objectives
- δ** State transition function

$$D = f(S, A, C, E)$$



5

Scenarios and Evaluation Framework



Representative scenarios:

- S1 – Unauthorised person
- S2 – Suspicious vehicle
- S3 – UAV intrusion
- S4 – Multiple intrusions
- S5 – False alarm
- S6 – Communication failure

Evaluation metrics:



Conceptual modelling study — experimental validation remains future work.

AI-Orchestrated Mission Management Framework

INTEGRATED SENSING

AI-ENABLED DECISION SUPPORT

AUTONOMOUS ASSETS

HUMAN-ON-THE-LOOP



1 SENSING LAYER

-  Radar
-  EO/IR
-  Thermal
-  Acoustic
-  RF / Spectrum

2 AI DECISION LAYER

-  Sensor fusion
-  Threat assessment
-  Mission planning
-  Task allocation
-  AI decision engine

3 AUTONOMOUS ASSETS LAYER

-  UAVs (reconnaissance, verification, tracking)
-  UGVs (inspection, persistent surveillance)

4 HUMAN-ON-THE-LOOP LAYER

-  Supervision & authority
-  Decision control
-  Safety and accountability
-  Human-AI teaming



-  Mission approval
-  Parameter modification
-  Override / Intervention
-  Termination



From Detection to Adaptive Mission Execution



Formal Representation of the Operational Decision Model



$$\text{ODM} = (S, E, A, C, D, O, \delta)$$

S



Operational states

Defined mission states (e.g., monitoring, detection, planning)

E



Events

External or internal events (e.g., intrusion, sensor alert)

A



Autonomous assets

Available UAVs, UGVs and supporting systems

C



Operational constraints

Environment, rules, resources, communication, safety

D



AI decision function

Selects the appropriate operational action

O



Mission objectives

Protection goals (e.g., detection, verification, neutralisation)

δ



State transitions

Rules for moving between states based on events and decisions

Inputs to decision function

S



Current state

A



Available assets

C



Constraints

E



Detected events

AI Decision Function

$$D = f(S, A, C, E)$$



Output

Selected operational action



Continue monitoring



Deploy UAV



Deploy UGV



Request operator approval



Other action

Technology-independent decision logic

Formalising the Mission Lifecycle



Explicit states and transitions enable simulation and verification.

Six Scenarios for Future Simulation-Based Testing

S1

Person Intrusion



S2

Suspicious Vehicle



S3

UAV Intrusion



S4

Multiple Intrusions



S5

False Alarm



S6

Communication Failure



Nominal

Dynamic

Multi-threat

Degraded conditions

From Conceptual Framework to Measurable Performance

1 Operational Scenarios



2 ODM Simulation



3 Performance Evaluation



4 Verification & Validation



Surveillance

- Detection time
- Identification time
- Coverage



Mission Performance

- Response time
- Mission success
- Completion time



Resource Efficiency

- UAV/UGV utilisation
- Allocation efficiency



Human Supervision

- Operator workload
- Intervention rate



What Does This Research Actually Contribute?



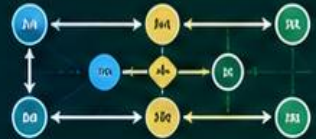
SCIENTIFIC CONTRIBUTION



Integrated
AI-OMMF architecture



Formal Operational
Decision Model



Simulation-ready
scenarios and metrics



Human supervisory
authority



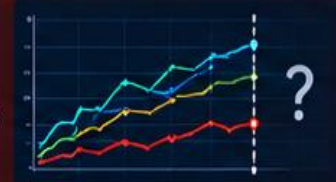
CURRENT LIMITATIONS



No experimental
validation yet



No measured
performance gains



Technology-
independent
abstraction



NEXT STEP

Simulation implementation
and comparative experiments



From Autonomous Platforms to Autonomous Mission Management

AUTONOMOUS PLATFORMS

Individual capabilities (platform-level autonomy)



UAV
Autonomous
reconnaissance



UGV
Autonomous
navigation



SENSORS
Automated
detection



AI
Threat
detection



HUMAN-AI
Information
interaction

AI-ORCHESTRATED MISSION SYSTEM

Adaptive • Coordinated • Human-Supervised • Simulation-Ready



» The next challenge is not more autonomy — it is **better orchestration.** «

Questions?

AI-Orchestrated Mission Management Framework

Ondřej Vozňák · University of Defence

