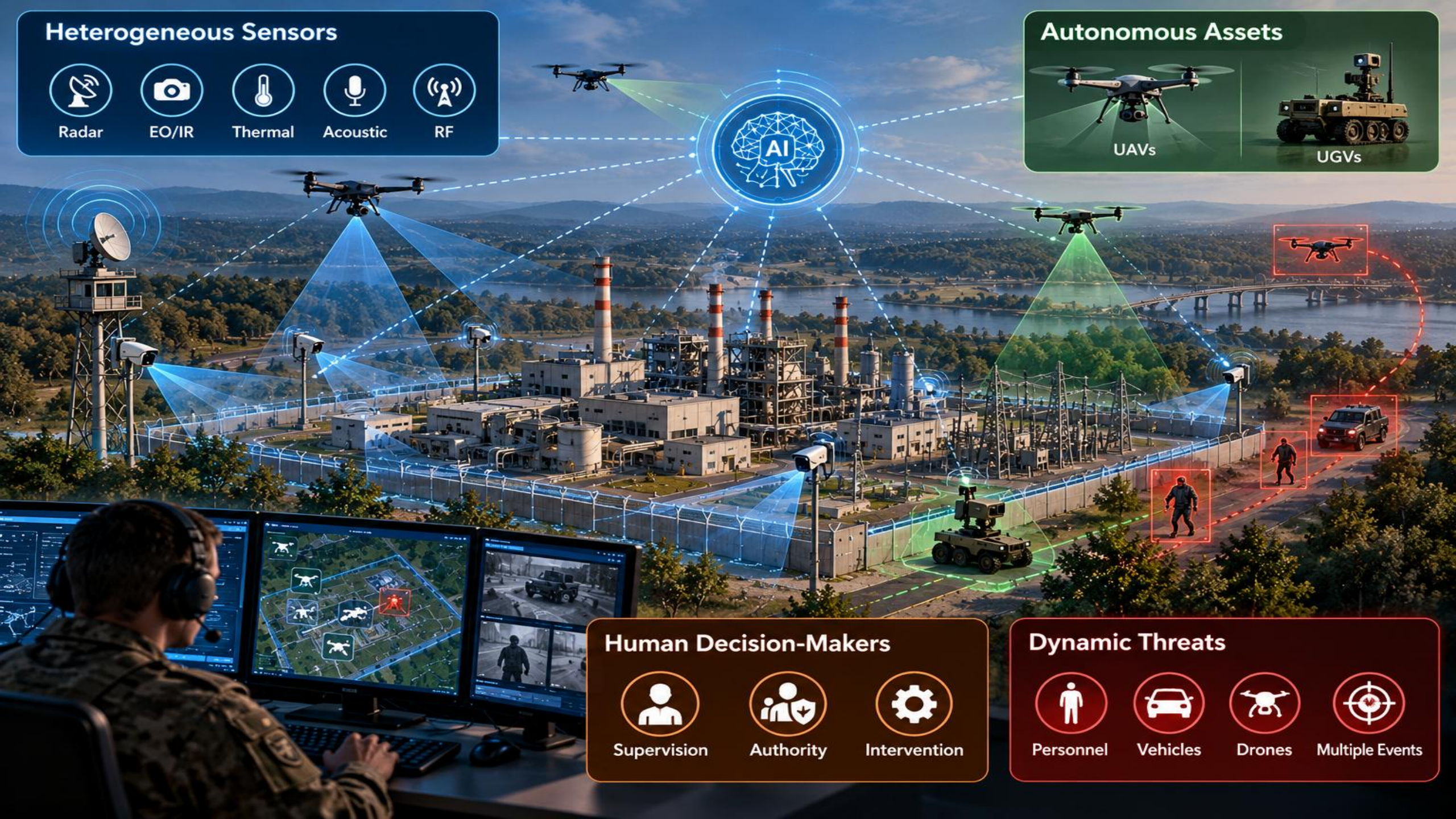


Simulation-Ready AI-Orchestrated Multi-Layer Autonomous Framework for Critical Infrastructure Protection

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Heterogeneous Sensors
Radar
EO/IR
Thermal
Acoustic
RF
AI
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

Sensing → Assessment → Planning → Allocation → Execution → Feedback

Human supervision



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

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

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:

- Surveillance effectiveness
- Mission performance
- Resource efficiency
- Human supervision



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



1 SENSE

2 FUSE

3 ASSESS

4 PLAN

5 ALLOCATE

6 EXECUTE

7 VERIFY / TRACK

CONTINUOUS FEEDBACK



Human Supervision

Approve | Modify | Override | Terminate

Continuous closed-loop mission management.

Formal Representation of the Operational Decision Model



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

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

1 Idle

2 Monitoring

3 Detection

4 Classification

5 Assessment

6 Planning

7 Deployment

8 Verification

9 Tracking

10 Mission Complete

New information / changed situation
(re-assessment, re-planning, re-allocation)



Explicit states and transitions enable simulation and verification.

Six Scenarios for Future Simulation-Based Testing



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

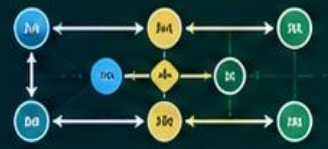
What Does This Research Actually Contribute?

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

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