

Swarm-Based Shahed Interception System: Multi-Sensor, Multi-Role, Resilient AI Coordination

Bullet Systems, Ukraine
June 2025

Mission Summary

A three-UAV swarm (Recon High, Recon Low, Strike) executes Shahed detection, tracking, jamming, and destruction in a 500x500 m search zone under electronic warfare (EW) threat. All units operate as a mesh network and can switch roles in real-time. System is designed for full autonomy, with operator in loop or override.

Advantages Over Manual Ops

- Swarm operation: ↑ detection probability by 60%, ↑ kill probability by 40%, ↓ dead-zones by 80% vs manual/solo UAV.
- Mesh comms: all-to-all links, jamming resilience, auto re-route on link loss.
- Vertical separation: full 3D coverage (no blind spots); dual confirmation before strike.
- Onboard AI: rapid sensor fusion, real-time decision, reduces operator load.

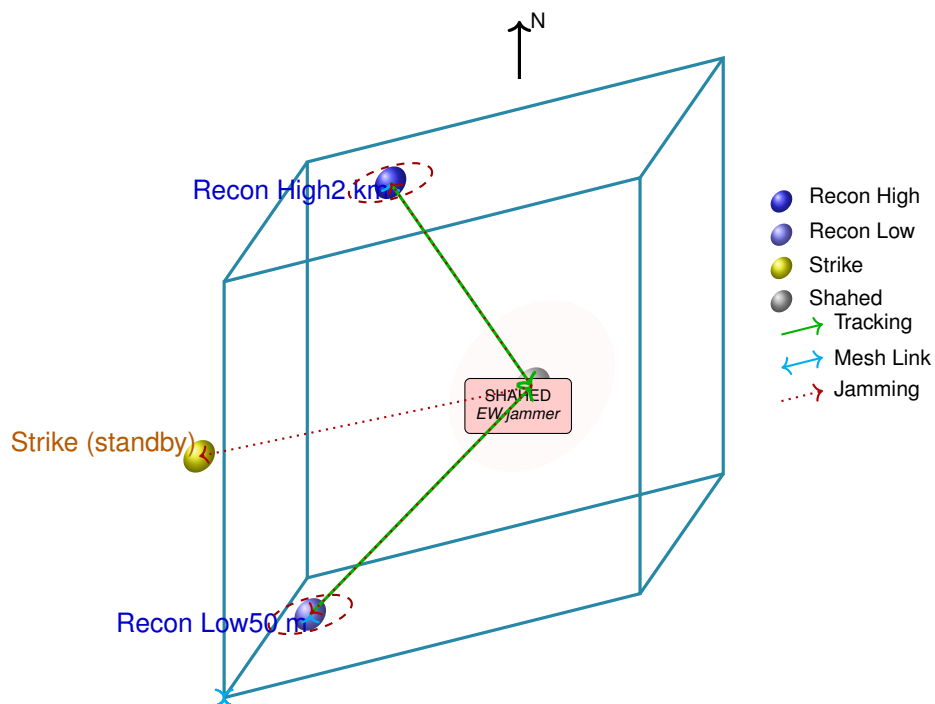
System Constraints and Risk Mitigation

- **Jamming by Target:** Shahed emits EW noise; swarm adapts by frequency hopping, directional antennas, and fallback to optical comms.
- **Weather:** Sensor effectiveness may degrade in fog/rain (thermal and radar compensate).
- **Fallback:** If any UAV lost, mesh network reroutes data; roles auto-switch (Recon → Strike).
- **Operator Override:** At any moment, operator can assume direct control or reassign roles.

Sensor Capability Table

Sensor	Max Range	Resolution	All-weather	Function
Thermal Imager	2000 m	$<0.5^\circ$	Yes	Wide-area detection
mmWave Radar	1200 m	<1 m	Yes	All-weather target lock
LiDAR	500 m	<0.2 m	No	Precise 3D profile
HD Camera	100 m	Full HD	No	Confirmation

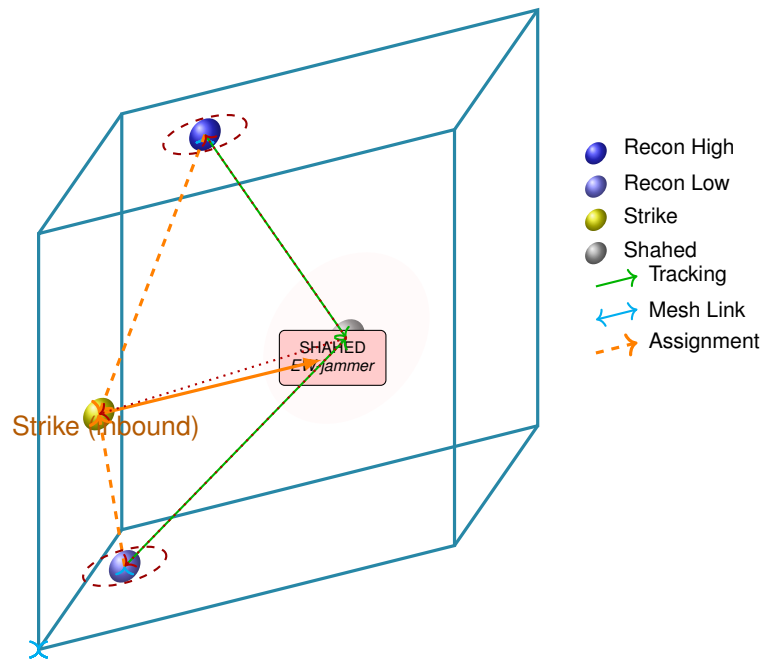
Phase 1: Detection, Tracking, Jamming (3D, Mesh, EW)



EW-jamming is always present. All-to-all mesh comms ensure network resilience. Recon High and Low provide redundant, vertical detection; jamming lines are visualized as red dotted arrows.

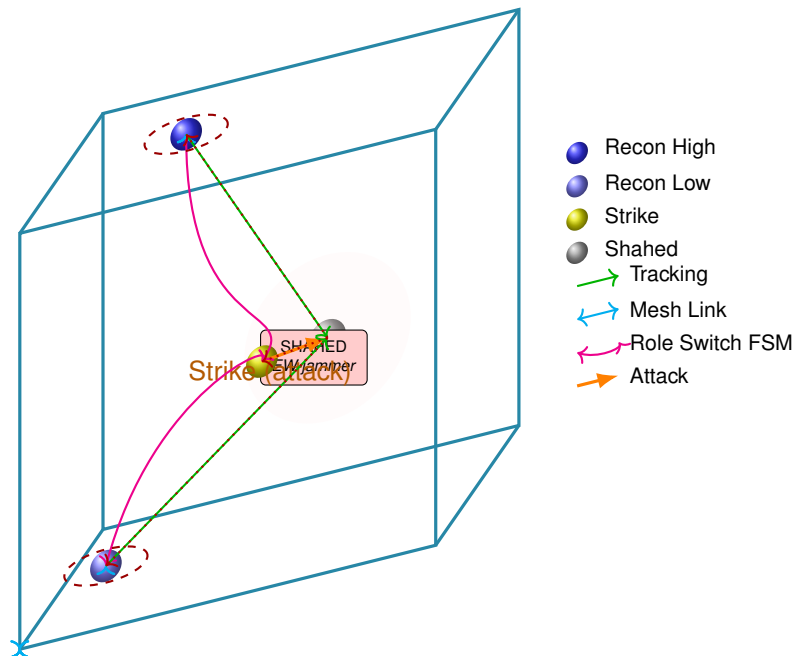
Phase 2: Assignment and Real-Time Guidance

Strike drone is dynamically assigned by mesh consensus. All recon drones send continuous updates despite jamming. Strike route is chosen for minimal exposure.



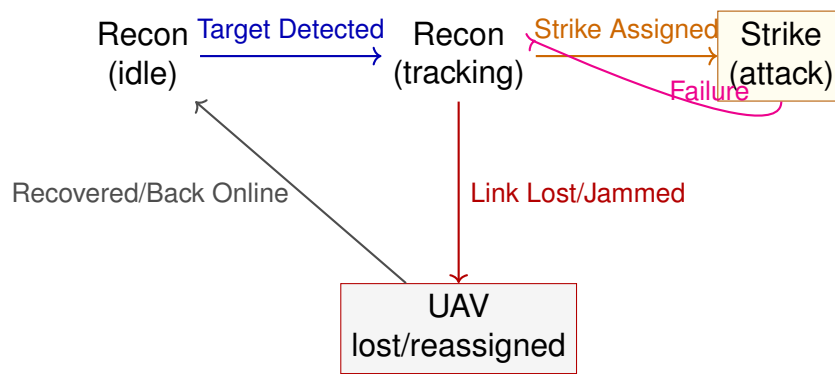
Phase 3: Attack, State-Switching, Confirmation

Strike executes attack with ongoing guidance; if lost, any Recon can take over (role switch FSM). Swarm continues tracking for BDA and jamming.

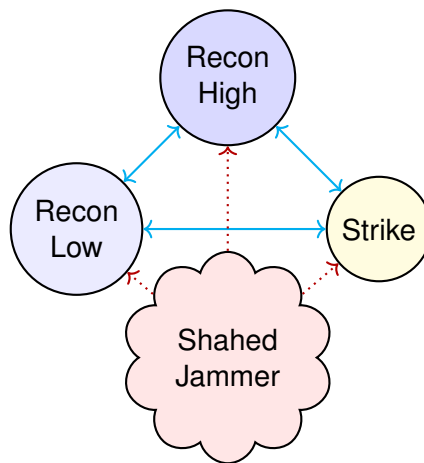


Role switching is supported: if Strike fails, any Recon can assume attack function (FSM arrows).

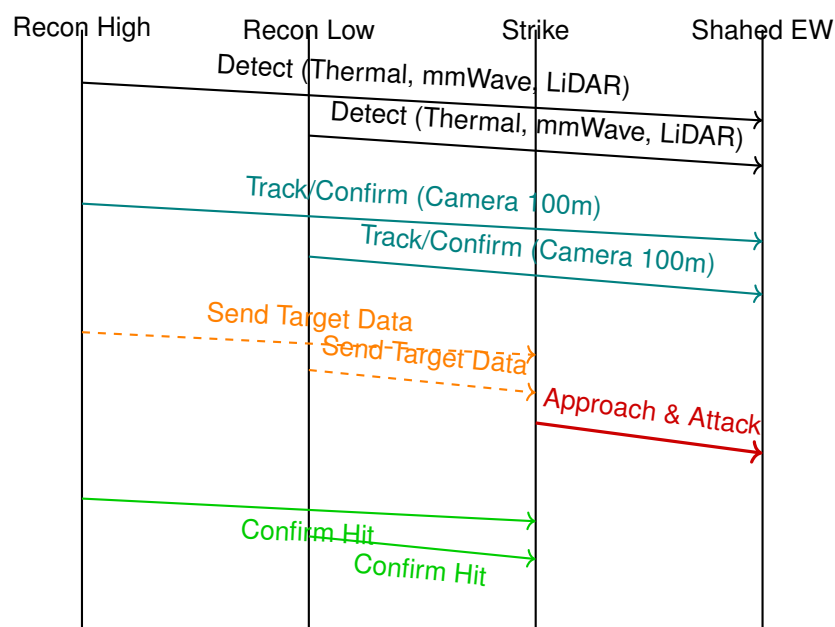
State Machine: Role Assignment



Mesh Network Topology



Swarm Algorithm: Sequence Diagram



Timing and Latency

End-to-end (Detection → Strike): 6–12 seconds typical.

Data latency: <0.5s (all-to-all mesh).

Fallback/role switch: <1s.

Scaling, Automation, AI

- Up to 10 UAVs per swarm supported, all auto-meshed.
- Any Recon can be reassigned as Strike or jammer.
- Onboard AI for sensor fusion and target ID; operator can confirm/override.
- Consensus algorithm (multi-vote) prevents false alarms.

Counter-Countermeasures and Resilience

- EW-resilient (jamming/frequency hopping), triple-layer comms (RF, mmWave, optical).
- Dynamic role assignment if jamming/loss detected.
- Data encrypted (AES-256); local autonomy if mesh lost.
- Recovery protocols: lost link → loiter → fallback mesh.

All diagrams, tables and protocols are designed for rapid adaptation to future drone swarms and threat models.