Policy Brief

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Short Citation:
Wu (2025), *From Predictive Control to Robustness*, EPINOVA Policy Brief 03.

From Predictive Control to Robustness: Why Indeterminacy Outperforms Precision in Contested ISR Environments

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Executive Summary

For much of the past decade, drone warfare has been evaluated through a precision-centric lens. Advances in sensing, data fusion, and command-and-control have reinforced the assumption that improved detection, tighter synchronization, and faster decision cycles translate into durable operational advantage. In increasingly contested ISR environments, this assumption no longer holds.

This policy brief argues that uncertainty in drone warfare is not merely a deficit of information but a structural condition produced by interaction, exposure, and adversary adaptation. Precision-centric approaches often accelerate opponent learning, compress decision windows, and undermine long-run effectiveness. This implies shifting assessment from static intercept rates to dynamic measures of adversary learning speed and exposure accumulation. By contrast, robustness-oriented postures that preserve spatiotemporal indeterminacy can raise adversary costs while offering alternative pathways to stability—if paired with appropriate governance mechanisms. The policy challenge is no longer how to see more, but how to prevent seeing enough from becoming cheap.

Key Findings:

- Precision-centric drone warfare models treat uncertainty as a deficit; in contested environments, uncertainty becomes a structural condition produced by adaptation and exposure.
- Improvements in sensing, synchronization, and control often accelerate adversary learning and degrade long-run effectiveness.
- Temporal regularity and persistent ISR generate exploitable patterns that undermine predictability-based control.
- Robustness-oriented postures that preserve spatiotemporal indeterminacy can raise adversary costs without requiring continuous activity.
- Traditional verification and escalation management frameworks are strained under conditions of contested observability.

1. The Policy Problem: When Precision Becomes Fragile

Drone warfare doctrines have long equated improved information with improved control. Persistent ISR, tighter timing, and centralized coordination are assumed to reduce miscalculation and stabilize interactions. These assumptions rest on a critical premise: that observation produces actionable certainty at acceptable cost.

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In contested environments, this premise breaks down. As sensing and communication systems become more capable, they also become more targetable. Efforts to improve positional or temporal certainty often generate countervailing costs: signature exposure, predictable activity patterns, and accelerated countermeasures. Here, indeterminacy does not mean signal absence or deception per se; it **denotes the persistent inability to convert observation into reliable certainty without incurring escalating strategic cost.**

The result is a structural trade-off. Precision in one dimension frequently erodes resilience in another. Continuous ISR improves situational awareness but increases detectability; tight synchronization enhances short-term effectiveness but creates exploitable temporal regularities; centralized control improves coordination but exposes communication dependencies. These dynamics are not failures of execution—they are intrinsic to contested observability.

2. Why Precision Fails Under Contestation

Three interacting mechanisms explain why precision-centric approaches become brittle in drone warfare.

First, a measurement–exposure trade-off. In contested ISR environments, observation quality is endogenous. Increased sensing, control, and persistence reveal patterns, thresholds, and dependencies that adversaries can exploit. Exposure accumulates over time, shaping the opponent's future ability to infer, anticipate, and counter.

Second, timing behaves as hazard, not schedule. Regular timing patterns are actively exploited by adversaries in contested environments, undermining predictability-based control logics and accelerating counter-adaptation. Treating frequency as a deterministic schedule misrepresents environments where activity regularity becomes a liability rather than an advantage.

Third, an interpretability gap emerges. Detection does not guarantee classification, and classification does not guarantee confident intent inference. As adversaries adapt, signals may be observable without being interpretable, widening the gap between what is seen and what can be acted upon.

Together, these mechanisms undermine the assumption that better information reliably produces better control.

3. Implications for Policy and Planning

3.1 Evaluation Metrics

Current evaluation frameworks prioritize point-performance indicators, such as intercept rates, detection persistence, and synchronization speed, that perform well in isolated

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engagements but systematically understate exposure costs and adversary learning dynamics.

As a result, these metrics overestimate long-run effectiveness under sustained contestation. Policymakers should shift evaluation criteria away from static performance outcomes toward dynamic measures of adversary learning speed, exposure accumulation, and the marginal cost required to achieve actionable certainty.

3.2 Force Planning

Single-regime optimization is increasingly risky. Postures optimized for peak effectiveness in one interaction regime can fail catastrophically when conditions shift. Portfolio-style approaches that distribute emphasis across multiple presence modes can improve robustness under regime uncertainty, even if they sacrifice peak performance in any single scenario.

3.3 Escalation Management

Precision-centric models implicitly assume that transparency and predictability stabilize interactions. In practice, tightly coupled sensing and timing can compress decision windows and amplify misinterpretation. Robustness-oriented approaches complicate verification but may reduce escalation pressure if paired with shared expectations and governance safeguards.

3.4 Governance and Verification

Force structures optimized for spatiotemporal indeterminacy complicate traditional verification and increase misperception and escalation risk, particularly under conditions of entangled sensing and autonomous adaptation. Static transparency loses traction when observability fails to deliver interpretability.

4. Policy Recommendations

- Reassess evaluation frameworks that prioritize precision without accounting for exposure, adaptation, and long-run robustness.
- Avoid single-regime optimization in force planning; favor posture mixtures resilient to regime shifts and adversary learning.
- Incorporate uncertainty as a stability variable in escalation management rather than treating it solely as a failure mode.
- Shift governance emphasis from continuous spatiotemporal transparency toward process-based accountability and audit-by-design mechanisms compatible with survivability.
- Develop signal management norms that reduce misinterpretation without requiring disclosure of sensitive operational details.

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