



EXCERPT FROM THE
PROCEEDINGS
OF THE
TWENTY-THIRD ANNUAL
ACQUISITION RESEARCH SYMPOSIUM AND
INNOVATION SUMMIT

WEDNESDAY, MAY 6, 2026 SESSIONS
VOLUME I

“ACCELERATING WARFIGHTING CAPABILITIES”

**Rapid Deployment of Airborne Directed Energy
Weapons: A Strategic Solution to Evolving Aerial Threats**

Published: April 30, 2026

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Prepared for the Naval Postgraduate School, Monterey, CA 93943.

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The research presented in this report was supported by the Acquisition Research Program, Graduate School of Defense Management at the Naval Postgraduate School.

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NAVAL POSTGRADUATE SCHOOL

Rapid Deployment of Airborne Directed Energy Weapons: A Strategic Solution to Evolving Aerial Threats

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Abstract

Modern aerial warfare is increasingly characterized by low-cost, high-volume threats such as unmanned aerial vehicles (UAVs) and cruise missiles, which challenge the economic and operational sustainability of traditional kinetic air defense systems. This paper examines the feasibility of rapidly deploying airborne Directed Energy Weapons (DEWs), specifically high-TRL solid-state lasers, as a strategic response to this imbalance. The research integrates technical analysis, operational scenario modeling, and acquisition strategy to define a realistic pathway for deployment within a three-year timeframe. A 30–50 kW class laser system is identified as the optimal balance between operational effectiveness and Size, Weight, Power, and Cooling (SWaP-C) constraints, enabling multiple engagements per sortie while remaining compatible with existing airborne platforms. Scenario-based analysis demonstrates that such systems can effectively counter high-volume UAV threats and enhance layered defense architectures by improving cost-exchange ratios and operational persistence. The study further argues that traditional acquisition processes are incompatible with current threat timelines and proposes the Middle Tier of Acquisition (MTA) as a critical enabler for rapid fielding. The findings indicate that airborne DEWs are not only technically feasible but strategically necessary, providing a scalable and sustainable solution for modern air defense.

Introduction

Modern aerial warfare is undergoing a structural transformation driven not by technological superiority alone, but by the growing dominance of low-cost, high-volume threats. Unmanned aerial vehicles (UAVs) and cruise missiles are increasingly employed as scalable, accessible, and economically efficient tools of warfare. As highlighted by Rassler (2024), these systems enable adversaries to project power at relatively low cost while exploiting vulnerabilities in traditional defense architectures. This shift has exposed a fundamental weakness in current air defense strategies: the inability to sustain a favorable cost-exchange ratio over time.

Conventional air defense systems rely heavily on kinetic interceptors such as surface-to-air missiles. While these systems are highly effective in terms of precision and lethality, they are constrained by both cost and inventory. Each engagement carries a significant financial burden, often reaching hundreds of thousands or even millions of dollars per interceptor. When employed against low-cost threats, this creates an economic imbalance that is strategically unsustainable. As demonstrated in recent operational contexts, defenders are increasingly forced into a reactive posture in which success in interception does not translate into long-term strategic advantage (Sayler et al., 2024).

This challenge is further exacerbated by the emergence of swarm tactics, where large numbers of inexpensive UAVs are used to saturate and overwhelm defense systems. Traditional interceptors, limited by magazine depth and reload constraints, are not designed to counter such high-volume attacks efficiently. As a result, the current defense paradigm is being stretched beyond its intended limits, requiring new approaches that can scale both operationally and economically.



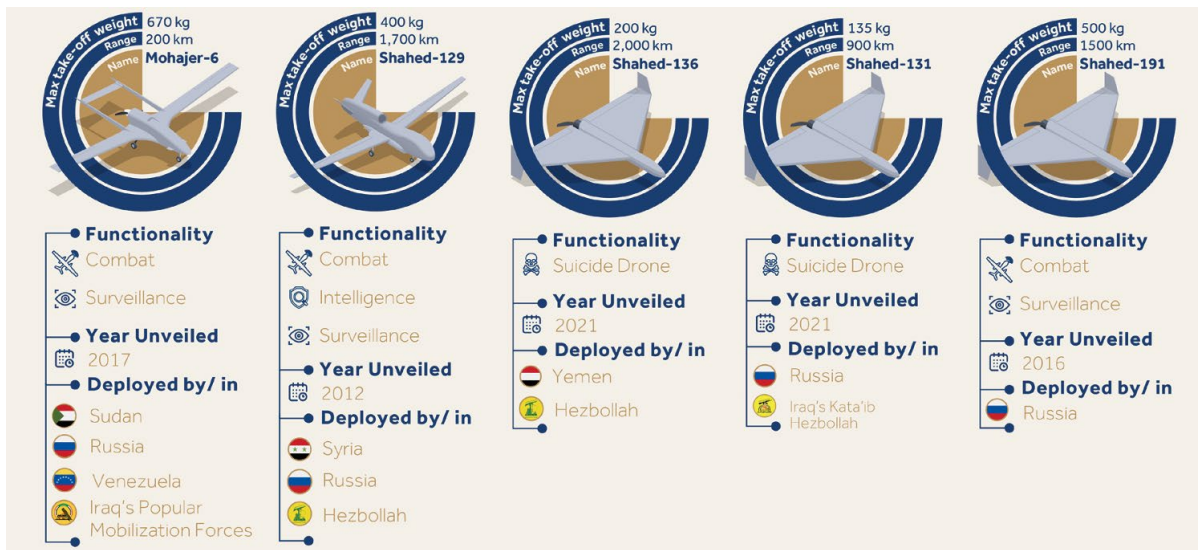


Figure 1. Iran Deadly Drone Arsenal Reach
(Middle East Council on Global Affairs, 2024)

Directed Energy Weapons (DEWs), and specifically solid-state laser systems, offer a promising alternative to this paradigm. Unlike kinetic interceptors, DEWs deliver energy directly to a target at the speed of light, enabling near-instantaneous engagement without the need for physical munitions. This fundamentally changes the cost structure of air defense, as the marginal cost per engagement is reduced to the cost of energy consumption, which is negligible compared to traditional interceptors (Johnson et al., 2023). Additionally, DEWs provide the potential for a “deep magazine,” limited primarily by onboard power generation rather than physical inventory.

The growing maturity of solid-state laser technology further strengthens the case for their operational deployment. Advances in beam control, power generation, and system miniaturization have brought these systems to a Technology Readiness Level (TRL) that supports near-term integration into military platforms (Blau et al., 2018; Weinberg, 2023). Real-world demonstrations, including systems such as ODIN and HELIOS, have already shown the feasibility of using directed energy to counter aerial threats in operational environments (Johnson, 2024; Saylor et al., 2024).

Despite these advancements, the transition from experimental systems to operational capability remains a significant challenge. Traditional defense acquisition processes are often characterized by long development cycles, complex requirements, and extensive oversight, which can delay the fielding of new technologies. In the context of rapidly evolving threats, such timelines are no longer acceptable. The central premise of this research is therefore that airborne DEWs must be deployed within a compressed timeframe—specifically, within three years—to remain operationally relevant.

To achieve this objective, the research adopts a pragmatic approach that prioritizes mature technologies and focuses on integration feasibility. Among the various DEW technologies evaluated, solid-state lasers emerge as the most suitable candidate due to their relatively high TRL, scalability, and compatibility with airborne platforms. The study identifies a 30–50 kW class laser system as a realistic “working point,” balancing operational effectiveness with the constraints imposed by size, weight, power, and cooling (SWaP-C) requirements. This configuration is expected to enable multiple engagements per sortie, providing meaningful operational impact while remaining feasible within existing platform limitations.

A key conceptual tension explored in this research is the balance between “technology push” and “requirement pull.” While cutting-edge technologies offer significant potential, their development timelines often exceed operational needs. Conversely, strictly requirement-driven approaches may limit innovation. This study proposes a hybrid approach, leveraging mature technologies while adapting them rapidly to meet urgent operational requirements. This perspective aligns with broader strategic frameworks that emphasize adaptability and iterative development in complex environments (Reeves et al., 2015).

In addition to technological considerations, the research addresses the broader system-level challenges associated with deploying airborne DEWs. These include integration into existing command-and-control architectures, development of operational doctrines, and implementation of safety and regulatory frameworks (Cannin, 2021). The complexity of these challenges highlights that the deployment of DEWs is not solely a technical problem, but also an organizational and strategic one.

Ultimately, this research seeks to answer a central question: How can DEWs be effectively integrated onto airborne platforms within a three-year timeframe to counter modern aerial threats in a cost-effective and sustainable manner? By combining technical analysis, operational scenario modeling, and acquisition strategy considerations, the study aims to provide a realistic and actionable framework for the rapid deployment of airborne DEWs.

The significance of this work extends beyond the specific application of directed energy. It represents a broader shift in how defense systems are conceptualized and developed in an era defined by asymmetric threats and rapid technological change. Airborne DEWs are not merely an incremental improvement—they are a potential enabler of a new defense paradigm, one that prioritizes sustainability, scalability, and strategic adaptability.

Problem Context

The contemporary defense environment is increasingly shaped by the proliferation of low-cost, high-volume aerial threats, particularly unmanned aerial vehicles (UAVs) and cruise missiles. These systems are not inherently advanced, but their effectiveness lies in their scalability, accessibility, and ability to exploit structural weaknesses in existing defense architectures. As highlighted by Ressler (2024), the evolution of such threats reflects a broader shift toward cost-efficient and distributed methods of warfare, where quantity and persistence can outweigh technological superiority.



Shahed-136 Drone ("Geran-2")

An Iranian-made suicide drone imported by Russia for use in its invasion of Ukraine. Rebranded as "Geran-2," or Geranium-2.

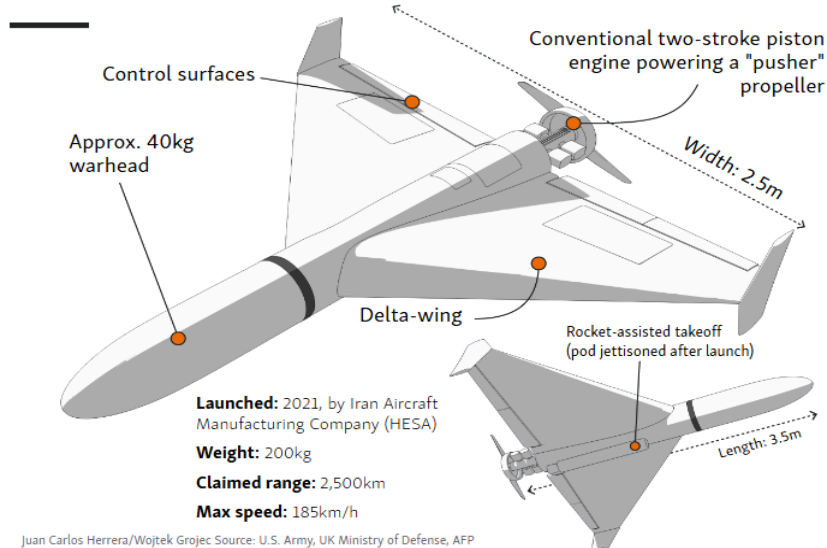


Figure 2. Iran Shahed 136 Key Performance Parameters

Traditional air defense systems were not designed for this type of threat environment. Their architecture is optimized for intercepting high-value targets using precision-guided kinetic interceptors. While effective against limited and sophisticated threats, these systems face significant limitations when confronted with large-scale, low-cost attacks. The fundamental issue is not the performance of individual interceptors, but the **economic and operational model** underlying their use.

Kinetic interceptors are expensive, finite, and logistically demanding. Each engagement consumes a physical asset that must be replenished, transported, and maintained. In contrast, UAVs and similar threats can be produced rapidly, at low cost, and deployed in large numbers. This creates a structural asymmetry in which the defender is forced to expend disproportionate resources to counter relatively inexpensive threats. As noted in Department of Defense assessments, this imbalance becomes particularly critical in scenarios involving swarm tactics, where saturation effects can overwhelm even advanced defense systems (Saylor et al., 2024).

The operational implications of this imbalance are significant. First, there is a limitation in **magazine depth**. Aircraft and ground-based systems can carry only a finite number of interceptors, which constrains their ability to sustain prolonged engagements. Second, there is a constraint on **engagement rate**, as kinetic systems require time for targeting, launch, and potential re-engagement. Third, and most critically, there is a **cost-exchange problem**, where the cumulative cost of defense exceeds the cost imposed on the attacker.

This dynamic is already evident in recent operational contexts. The increasing use of UAV swarms and missile barrages has demonstrated the vulnerability of traditional systems to saturation attacks, particularly when defenders are required to allocate high-value interceptors against low-value targets. As Johnson (2024) observes in the context of recent maritime operations, directed energy systems have begun to emerge as a response to precisely this challenge, offering a more sustainable engagement model.

Directed Energy Weapons (DEWs), particularly solid-state lasers, directly address the core limitations of kinetic systems. Unlike traditional interceptors, DEWs do not rely on physical

munitions and therefore are not constrained by magazine depth in the conventional sense. Instead, their operational limits are defined by power generation and thermal management. This enables a fundamentally different engagement paradigm, where multiple targets can be engaged sequentially with minimal marginal cost (Johnson et al., 2023).

However, while DEWs offer clear theoretical advantages, their practical implementation introduces a new set of challenges. The airborne environment imposes strict constraints on size, weight, power, and cooling (SWaP-C), which directly impact the feasibility of integrating laser systems onto existing platforms. As demonstrated in prior research on laser integration, achieving a balance between system performance and platform limitations is one of the most critical design challenges (Blau et al., 2018).

In addition to technical constraints, there are significant operational and doctrinal considerations. DEWs must be integrated into existing command-and-control architectures and used in conjunction with kinetic systems to form a layered defense. This requires the development of new engagement concepts that leverage the strengths of both approaches. Furthermore, safety considerations—such as preventing unintended exposure to friendly forces or civilian assets—must be addressed through robust control mechanisms and operational procedures (Cannin, 2021).

Another critical dimension of the problem is the timeline. Traditional defense acquisition processes are not aligned with the pace of threat evolution. Programs often require extensive development cycles, which delay the transition from prototype to operational capability. As emphasized in acquisition and innovation literature, bridging this gap requires more adaptive and flexible approaches that can accelerate development while managing risk (GAO, 2023; Reeves et al., 2015).

This research frames the problem as a **multi-dimensional challenge** involving:

- Economic imbalance (cost-exchange ratio)
- Operational constraints (magazine depth, engagement rate)
- Technical limitations (SWaP-C integration)
- Organizational barriers (acquisition timelines and processes)

The central argument is that addressing only one of these dimensions is insufficient. A viable solution must operate across all four simultaneously.

Therefore, the focus of this study is not simply on evaluating DEWs as a technology, but on assessing their feasibility as an **integrated operational and acquisition solution**. Specifically, the research examines whether a high-TRL solid-state laser system can be deployed on an airborne platform within a three-year timeframe while maintaining operational effectiveness and economic viability.

By situating the problem within this broader systemic context, the research moves beyond a purely technical discussion and establishes the foundation for a comprehensive solution. The following sections build on this foundation by examining the technological options, operational scenarios, and acquisition pathways that can enable the rapid deployment of airborne DEWs in response to evolving aerial threats.

Technological Comparison and Selection

The selection of an appropriate Directed Energy Weapon (DEW) technology for airborne deployment is not merely a technical decision, but a strategic one. It directly determines the feasibility of meeting the central requirement of this research: achieving an operational



capability within a three-year timeframe. While multiple DEW technologies have been developed over the past decades, their suitability varies significantly when evaluated against criteria such as technological maturity, integration feasibility, operational effectiveness, and logistical sustainability.

Three primary categories of laser-based DEWs are considered in this analysis: **chemical lasers, free electron lasers (FELs), and solid-state lasers (SSLs)**. Each represents a different point along the spectrum of power, complexity, and maturity.

Chemical lasers were among the earliest high-energy laser systems developed for military applications. They are capable of generating very high power levels and have demonstrated effectiveness in controlled environments. However, their operational use is constrained by significant logistical and safety challenges. Chemical lasers rely on hazardous reactants, require complex handling procedures, and impose substantial weight and volume burdens on the platform. These characteristics make them unsuitable for airborne integration, particularly under the strict Size, Weight, Power, and Cooling (SWaP-C) constraints identified in this research. As a result, despite their high output potential, chemical lasers are not considered viable for rapid deployment scenarios (Blau et al., 2018).

FELs represent a more advanced and flexible technological approach. They offer the potential for extremely high power output and tunable wavelengths, enabling adaptability across different operational conditions. However, FELs remain at a relatively low Technology Readiness Level (TRL) and require large, complex infrastructures that are incompatible with airborne platforms. Their size, power requirements, and developmental maturity place them firmly outside the scope of a three-year deployment timeline. While FELs may play a role in future high-power applications, they do not meet the near-term operational requirements defined in this study (Weinberg, 2023).

In contrast, SSLs provide a balanced solution that aligns closely with both technical and operational constraints. SSLs have reached a relatively high level of maturity, with many systems demonstrating TRL levels between 6 and 8. This maturity is reflected in recent operational demonstrations and ongoing programs, where SSLs have been successfully integrated into land-based and maritime platforms (Johnson, 2024; Saylor et al., 2024). Their architecture allows for modular scaling of power, improved reliability, and reduced logistical complexity compared to chemical systems.

From an operational perspective, SSLs offer several critical advantages. First, they enable **low-cost engagements**, as the primary resource consumed is electrical energy rather than physical munitions. Second, they provide **speed-of-light engagement**, which eliminates time-of-flight constraints and improves effectiveness against fast or maneuvering targets. Third, they support **scalability**, allowing system performance to be adjusted through incremental increases in power output (Johnson et al., 2023).

However, the selection of SSLs does not eliminate all challenges. Their integration into airborne platforms introduces significant constraints related to power generation, thermal management, and beam quality. Atmospheric effects, including turbulence and absorption, can degrade laser performance and must be mitigated through advanced beam control and adaptive optics (Sabatini et al., 2015; Shi et al., 2023). These limitations highlight the importance of selecting not only the appropriate technology type, but also the appropriate **power level**.

A key contribution of this research is the identification of a realistic “working point” for airborne DEWs. Rather than pursuing maximum power output, which would exceed platform constraints, the study focuses on achieving a balance between effectiveness and feasibility. The analysis indicates that a **30–50 kW class solid-state laser** represents the optimal range for



near-term deployment. Within this range, the system can deliver meaningful operational effects—such as neutralizing UAVs within tactically relevant engagement times—while remaining compatible with the SWaP-C limitations of existing aircraft.

This approach reflects a deliberate shift from a “maximum capability” mindset to a “**sufficient capability**” framework. The objective is not to replace kinetic systems across all threat types, but to provide a complementary capability that addresses the specific challenge of high-volume, low-cost threats. Even with limited dwell time and engagement range, a system in this power class can significantly reduce the burden on traditional interceptors by absorbing a substantial portion of incoming threats.

The selection of solid-state lasers, therefore, is not based solely on their theoretical advantages, but on their ability to meet a complex set of constraints simultaneously. They represent the only DEW technology that satisfies the combined requirements of:

- High technological maturity
- Feasible airborne integration
- Operational effectiveness against UAV-class threats
- Compatibility with a three-year deployment timeline

This conclusion reinforces the broader argument of the research: that rapid deployment is achievable only by aligning technological ambition with practical constraints. By focusing on solid-state lasers within a defined power range, the study establishes a credible foundation for the subsequent analysis of system integration, operational performance, and acquisition strategy.

Key Performance Parameters (KPPs) and System Design

The transition from conceptual analysis to an operationally viable solution requires the definition of clear and achievable Key Performance Parameters (KPPs). These parameters serve as the bridge between technological capability and mission effectiveness, ensuring that the proposed Directed Energy Weapon (DEW) system is not only theoretically sound but also practically deployable within the constraints identified throughout this research.

Rather than optimizing for maximum performance, this study adopts a **constraint-driven design approach**, where system parameters are derived from the intersection of operational requirements and platform limitations. This approach reflects the central premise of the research: that rapid deployment within a three-year timeframe requires prioritizing feasibility, integration, and sufficiency over technological perfection.

The primary constraint shaping system design is the airborne environment, which imposes strict limitations on size, weight, power, and cooling (SWaP-C). As demonstrated in prior studies on laser integration, these constraints are often the decisive factor in determining whether a system can transition from prototype to operational capability (Blau et al., 2018). Consequently, the definition of KPPs must begin with an understanding of what can realistically be integrated onto existing platforms without extensive redesign.

Based on this framework, the research identifies a **30–50 kW class solid-state laser** as the optimal power range for airborne deployment. This range represents a critical balance point. At lower power levels, the system’s ability to achieve reliable target neutralization within operationally relevant timeframes is limited. At higher power levels, the demands on power generation, thermal management, and structural integration exceed what can be accommodated within current airborne platforms.



Within this range, the study converges on a **30 kW system as the primary working point**, providing a realistic and testable configuration. This selection is supported by both engineering considerations and operational modeling, which indicate that such a system can achieve meaningful effects against UAV-class threats while remaining compatible with SWaP-C constraints.

Several KPPs emerge from this analysis:

- First, **laser power output**, defined at approximately 30 kW, represents the minimum threshold required to achieve effective engagement against small UAVs within tactically acceptable dwell times. This level of power enables the system to deliver sufficient energy to critical components of the target, resulting in mission kill rather than complete destruction, which aligns with the objective of efficient threat neutralization.
- Second, **effective engagement range**, estimated at approximately 5–7 kilometers, reflects the balance between beam propagation limitations and operational relevance. Atmospheric effects such as absorption, scattering, and turbulence impose constraints on laser performance, requiring careful optimization of engagement distances (Sabatini et al., 2015). Within this range, the system can operate effectively while maintaining integration feasibility.
- Third, **engagement capacity per sortie**, estimated at approximately 10–20 targets, represents a critical metric for evaluating operational value. Unlike kinetic systems, where each engagement consumes a physical interceptor, DEWs allow for multiple sequential engagements limited primarily by power availability and thermal constraints. This capability significantly enhances mission endurance and reduces dependence on resupply.
- Fourth, **system weight**, constrained to approximately 3,000 pounds or less, is essential for maintaining aircraft performance and avoiding major structural modifications. This requirement reinforces the need for a pod-based solution, where the DEW system is integrated as a modular unit rather than as a fully embedded subsystem.
- Fifth, **power and thermal management requirements** define the supporting infrastructure needed to sustain laser operation. These include onboard power generation, energy storage, and cooling systems capable of maintaining performance under continuous operation. Advances in energy storage and thermal management technologies are critical enablers in this context (Kim, 2024; Sylvester, 2014).

Together, these parameters define a system that is not optimized for maximum destructive capability, but for **operational relevance within real-world constraints**. This distinction is essential. The objective is not to replace kinetic interceptors across all threat categories, but to provide a complementary capability that addresses the specific challenge of high-volume, low-cost threats.



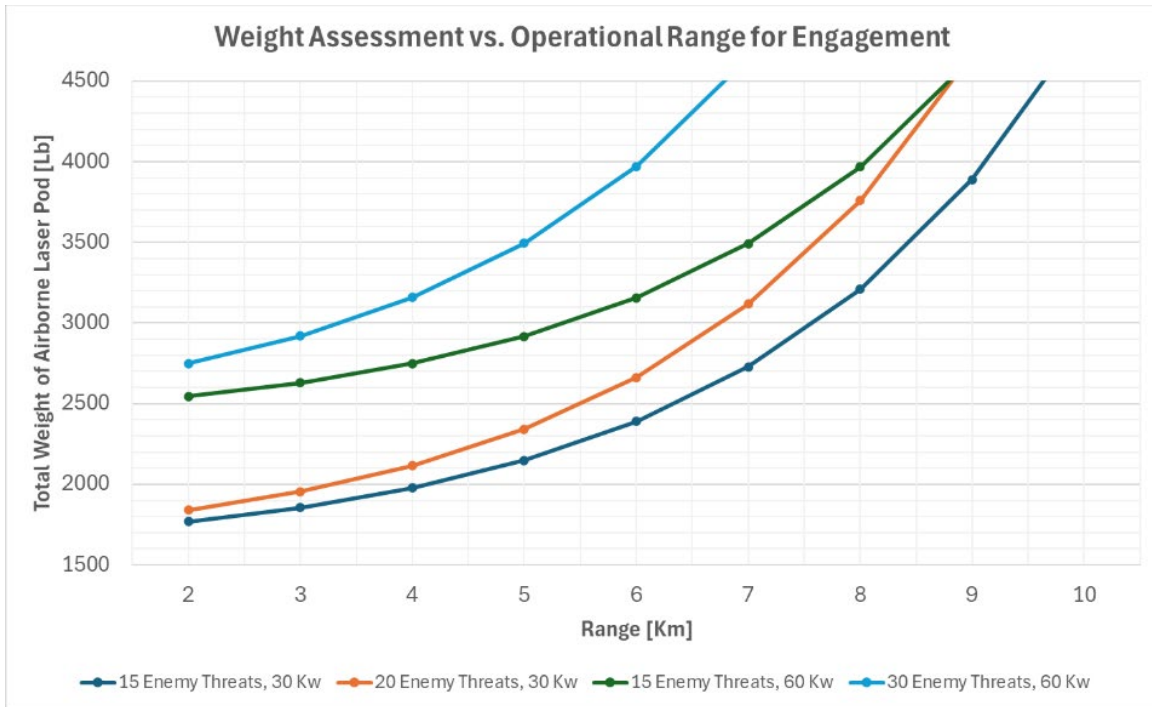


Figure 3. Total Weight of Airborne Laser Pod: Weight Assessment vs. Operational Range for Different Power and Number of Enemy Threats in One Sortie

To validate the operational implications of these KPPs, the research incorporates scenario-based modeling that simulates engagements between an airborne DEW-equipped platform and multiple UAV threats. The results indicate that a system within the defined parameter space can successfully neutralize multiple targets within a single sortie, with engagement times that are consistent with real-world operational requirements. These findings support the conclusion that even a relatively moderate-power system can deliver disproportionate operational value when evaluated within the broader context of cost efficiency and system sustainability.

An important insight emerging from this analysis is the concept of **“sufficient lethality.”** Unlike kinetic systems, which are often designed for complete target destruction, DEWs can achieve mission success through partial damage to critical components. This reduces the energy required per engagement and allows the system to maximize the number of targets addressed within a given mission.

Furthermore, the defined KPPs align closely with the constraints of rapid acquisition and deployment. By limiting system complexity and focusing on achievable performance thresholds, the design supports iterative development and testing, which are essential for meeting the three-year timeline. This approach is consistent with adaptive acquisition strategies that emphasize incremental capability delivery over long-term optimization (Reeves et al., 2015).

In summary, the KPPs defined in this research represent a carefully balanced solution that integrates technological capability, operational requirements, and platform constraints. The identification of a 30 kW-class solid-state laser as the system’s core element provides a credible and actionable foundation for the subsequent analysis of integration, operational employment, and acquisition strategy.



Operational Scenarios and System Validation

The definition of Key Performance Parameters (KPPs) provides a necessary foundation for system design, but it is insufficient on its own to establish operational relevance. To evaluate the effectiveness and scalability of airborne Directed Energy Weapons (DEWs), this research employs a scenario-based approach, examining how the proposed system performs under realistic and diverse operational conditions. This approach aligns with established principles of defense analysis, which emphasize the importance of contextual validation in complex and uncertain environments (Danzig, 2011).

Two distinct operational scenarios are used to test the robustness of the proposed solution. These scenarios are deliberately selected to represent different ends of the conflict spectrum: a localized, high-intensity environment characterized by UAV swarm threats and a broader, strategic environment involving long-range missile and UAV campaigns. Together, they provide a comprehensive framework for assessing both tactical effectiveness and strategic scalability.

The first scenario reflects a short-range, high-volume threat environment, similar to those observed in conflicts involving non-state actors such as Hezbollah. In this context, UAV swarms and short-range missiles are used to saturate defense systems through continuous and distributed attacks. These threats are characterized by low individual cost, high frequency, and the ability to exploit gaps in air defense coverage. Traditional kinetic systems struggle in such environments due to their limited magazine depth and high cost per engagement.

Within this scenario, airborne DEWs provide a critical advantage. By enabling multiple engagements per sortie with minimal marginal cost, the system can absorb a significant portion of the incoming threat volume. The ability to engage targets sequentially, without reliance on physical munitions, allows the platform to maintain operational effectiveness even during prolonged engagements. This directly addresses one of the core limitations of kinetic systems: the inability to sustain high engagement rates against large numbers of targets.

The second scenario represents a long-range, state-level conflict, such as a large-scale missile and UAV campaign driven by actors like Iran, with potential relevance to future operations in theaters such as INDOPACOM. In this environment, threats include not only UAVs but also more advanced systems, including long-range cruise missiles and coordinated strike packages. The scale and complexity of such scenarios require a defense architecture that is both layered and scalable.

In this context, airborne DEWs are not expected to replace kinetic systems, but to enhance them. Their role is to act as a **force multiplier**, reducing the burden on high-value interceptors by neutralizing lower-tier threats. By filtering out high-volume, low-cost targets, DEWs allow kinetic systems to focus on more complex and high-priority threats. This layered approach increases overall system efficiency and resilience, particularly in scenarios where resource allocation becomes a critical factor.

To support these scenario analyses, the research incorporates operational modeling of engagement dynamics. The modeling focuses on interactions between an airborne DEW-equipped platform and multiple UAV threats within a defined battlespace. Parameters such as target speed, engagement range, and dwell time are used to simulate realistic conditions. The results indicate that a 30 kW-class system can successfully neutralize multiple UAVs within a single engagement window, with dwell times that are consistent with known laser performance characteristics (Shi et al., 2023).

A key finding from this modeling is the system's ability to maintain a favorable engagement tempo. Unlike kinetic systems, which are constrained by reload cycles and



interceptor availability, the DEW system can transition rapidly between targets. This enables it to handle sequential engagements efficiently, making it particularly effective against swarm-based threats. The cumulative effect is a significant increase in the number of targets that can be addressed per sortie, reinforcing the system’s role as a scalable solution.

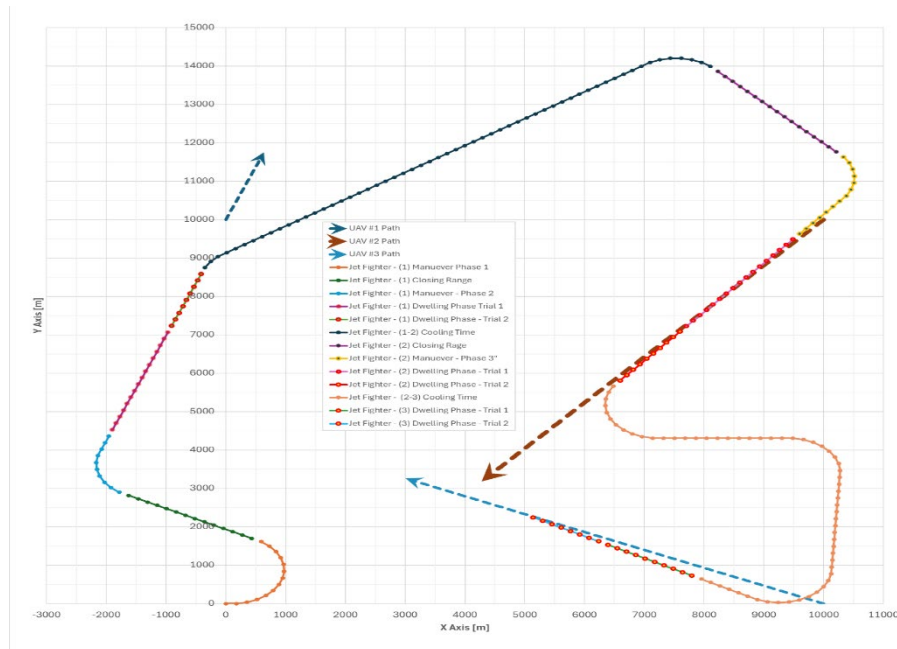


Figure 4. Dynamic Simulation of Jetfighter Against 3 UAV Threat in a Square Area of 10 km²

Another important aspect of the analysis is **fleet-level scalability**. While a single aircraft equipped with a DEW system can provide localized defense, the full operational value emerges when multiple platforms are integrated into a coordinated network. In such a configuration, DEW-equipped aircraft can be distributed across the battlespace, providing overlapping coverage and enhancing overall system redundancy. This distributed approach aligns with modern concepts of multi-domain operations, where flexibility and adaptability are critical to mission success.

The research also examines the implications of using a single DEW configuration across multiple scenarios. Given the constraints of the three-year deployment timeline, developing separate systems for different threat environments is not feasible. Instead, the study emphasizes the importance of a **multi-role system** capable of adapting to both localized and strategic contexts. The 30–50 kW class system identified in this research meets this requirement, offering sufficient flexibility to operate effectively across a range of scenarios.

In addition to operational effectiveness, the scenarios highlight the importance of integration with command-and-control (C2) systems. Effective use of DEWs requires real-time target identification, prioritization, and engagement coordination. This necessitates seamless integration with existing sensor networks and decision-making frameworks. Open architecture interfaces and standardized communication protocols are essential to enabling this integration and ensuring that DEWs can function as part of a cohesive defense system (Lazov et al., 2021).

Finally, the scenario analysis reinforces the broader strategic value of airborne DEWs. Their ability to provide persistent, low-cost engagement capability enhances not only tactical effectiveness but also overall system resilience. By reducing dependence on finite resources

and enabling sustained operations, DEWs contribute to a more sustainable defense posture in the face of evolving threats.

In summary, the operational scenarios demonstrate that the proposed airborne DEW system is not only technically feasible but also operationally relevant across a range of conflict environments. The combination of tactical effectiveness, scalability, and integration potential supports the conclusion that DEWs can play a central role in future air defense architectures, provided they are deployed within an appropriate strategic and organizational framework.

Acquisition Strategy and Rapid Deployment Framework

The feasibility of airborne Directed Energy Weapons (DEWs) is not determined solely by technological maturity or operational effectiveness. The decisive factor is whether these capabilities can be **acquired, integrated, and fielded within an operationally relevant timeframe**. In the context of rapidly evolving aerial threats, traditional defense acquisition processes are no longer sufficient. The central challenge, therefore, is not only technological—but organizational and procedural.

Conventional acquisition frameworks within the Department of Defense are designed to minimize risk through extensive requirements definition, sequential development phases, and rigorous oversight. While this approach has proven effective for large, complex systems, it typically results in development timelines exceeding a decade. Such timelines are fundamentally incompatible with the pace at which threats such as UAV swarms and low-cost missile systems are evolving. As highlighted by the Government Accountability Office (GAO, 2023), one of the most persistent challenges in defense innovation is the “valley of death,” where promising technologies fail to transition into operational capability due to bureaucratic and programmatic barriers.

To address this gap, this research proposes the use of the **Middle Tier of Acquisition (MTA)** as the primary acquisition pathway for airborne DEWs. The MTA framework is specifically designed to accelerate the development and fielding of capabilities by reducing procedural constraints and enabling iterative development. It provides two complementary pathways: rapid prototyping and rapid fielding. Together, these pathways offer a structured yet flexible approach to achieving operational capability within a compressed timeline.

The rapid prototyping phase focuses on developing and demonstrating a functional system within a 12–24-month period. In the context of airborne DEWs, this phase includes the design and construction of a pod-based laser system, integration with a host platform, and initial ground-based testing. The emphasis is on validating core functionalities—power generation, beam control, and thermal management—rather than achieving full operational optimization. This aligns with the broader principle of prioritizing **minimum viable capability** over maximum performance.

The rapid fielding phase builds on the results of prototyping and focuses on transitioning the system into operational use. This includes flight testing, refinement of system integration, development of operational procedures, and initial deployment within an operational unit. The objective is to achieve Initial Operational Capability (IOC) within a total timeframe of approximately three years. This accelerated timeline is consistent with adaptive acquisition strategies that emphasize speed, iteration, and user feedback (Reeves et al., 2015).

A key enabler of this approach is the adoption of a **modular, pod-based architecture**. By integrating the DEW system as an external pod rather than a fully embedded subsystem, the program avoids the need for extensive aircraft redesign. This significantly reduces integration risk, shortens development timelines, and allows for parallel testing across multiple platforms.



The modular approach also supports scalability, enabling future upgrades without requiring major structural modifications.

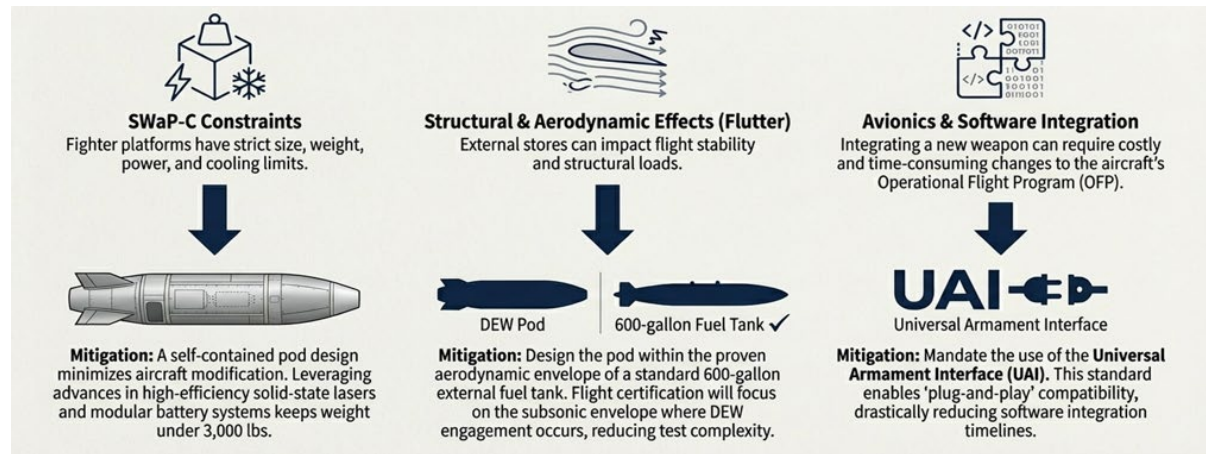


Figure 5. A Pragmatic Approach to De-Risking Complex Integration

Another critical element of the acquisition strategy is the use of **iterative development and spiral upgrades**. Rather than attempting to deliver a fully optimized system in a single step, the program evolves through successive increments. Each iteration introduces improvements in power, efficiency, and integration while maintaining operational capability throughout the process. This approach reduces risk by allowing issues to be identified and addressed early, and it aligns with best practices in modern defense innovation.

Risk management is a central component of the acquisition framework. The primary risks associated with airborne DEWs include power generation, thermal management, beam control, and system integration. These risks are mitigated through a combination of technology selection, system design, and testing strategy. For example, the use of high-TRL solid-state lasers reduces technological uncertainty, while the pod-based architecture minimizes integration complexity. Advanced modeling tools, including digital twins and predictive analytics, further support risk reduction by enabling early identification of potential issues and optimization of system performance (Weinberg, 2023).

In addition to technical risks, the acquisition strategy must address organizational and regulatory challenges. Effective coordination between military stakeholders, industry partners, and regulatory bodies is essential to ensure alignment of requirements, resources, and timelines. Open architecture principles play a key role in this context, enabling interoperability and facilitating integration with existing command-and-control systems (Lazov et al., 2021).

The integration of **Systemic Operational Design (SOD)** principles provides an additional layer of strategic coherence to the acquisition process. SOD emphasizes the importance of understanding complex systems as dynamic and interconnected, where tensions and constraints can be leveraged to drive innovation. In this research, the three-year deployment timeline is framed as a “productive tension,” forcing prioritization, accelerating decision-making, and encouraging creative problem-solving (Graicer, 2017). This perspective shifts the focus from eliminating constraints to using them as drivers of efficiency and innovation.

An important consideration within the acquisition strategy is whether to adopt an intermediate step, such as integrating the DEW system onto a larger transport aircraft before transitioning to fighter platforms. While this approach may reduce initial risk by providing a more permissive integration environment, it also introduces potential delays and additional program

complexity. This research argues that, given the urgency of the operational requirement, a direct path to fighter integration—supported by modular design and incremental testing—offers a more effective balance between risk and speed.

Ultimately, the proposed acquisition framework reflects a fundamental shift in how defense capabilities are developed and fielded. It moves away from a linear, risk-averse model toward a more agile and adaptive approach that prioritizes speed, flexibility, and operational relevance. This shift is not optional; it is a necessary response to a threat environment that evolves faster than traditional acquisition processes can accommodate.

In summary, the rapid deployment of airborne DEWs is achievable not only because the technology is sufficiently mature, but because acquisition frameworks such as MTA provide the means to translate that maturity into operational capability. By aligning technology, system design, and acquisition strategy within a coherent framework, this research demonstrates that a three-year deployment timeline is both realistic and attainable.

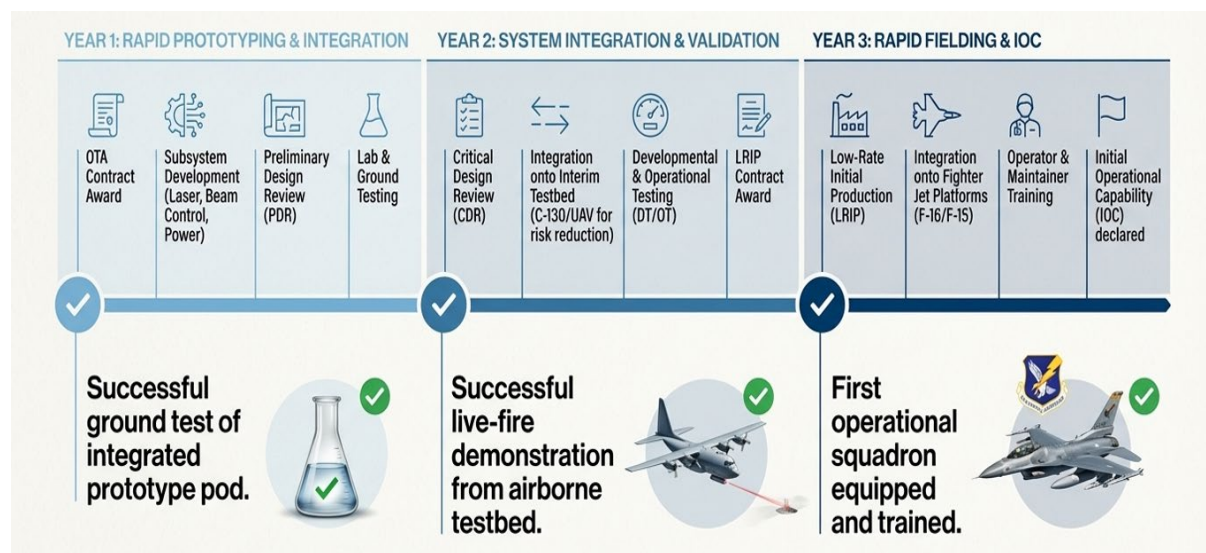


Figure 6. Three-Year Path to Capability

Strategic Implications and Conclusions

The rapid deployment of airborne Directed Energy Weapons (DEWs) represents more than a technological advancement; it reflects a fundamental shift in the logic of air defense. The findings of this research demonstrate that DEWs are not merely an incremental improvement to existing systems, but a capability that alters the underlying balance between offense and defense in modern aerial warfare.

At the core of this transformation is the **cost-exchange dynamic**. Traditional kinetic systems impose a structural disadvantage on defenders, forcing them to expend high-value interceptors against low-cost threats. Over time, this creates an unsustainable model, where even successful defenses erode strategic resources. As highlighted in prior analyses, this imbalance is already evident in operational environments characterized by UAV swarms and missile saturation attacks (Sayler et al., 2024).

Airborne DEWs directly address this challenge by fundamentally reducing the marginal cost of engagement. By shifting the constraint from inventory to energy, they enable a more sustainable defense posture, where the defender can match or exceed the attacker's scale without proportional increases in cost. This transition is not simply economic—it is strategic. It

restores the defender’s ability to absorb high-volume attacks without degrading long-term readiness.

Beyond cost considerations, DEWs introduce a new level of **operational persistence**. Unlike kinetic systems, which are limited by magazine depth and reload cycles, DEWs can sustain engagements as long as sufficient power is available. This creates a continuous defensive capability that is particularly effective against swarm-based threats. In this sense, DEWs transform air defense from a sequence of discrete engagements into a **persistent engagement environment**, where threats can be addressed dynamically and continuously.

Another important implication is the impact on **force design and layered defense architectures**. The integration of DEWs enables a more efficient allocation of resources across different threat tiers. High-cost kinetic interceptors can be reserved for complex, high-value targets, while DEWs handle high-volume, low-cost threats. This layered approach increases overall system efficiency and enhances resilience against saturation attacks. It also aligns with broader concepts of multi-domain operations, where flexibility and adaptability are critical to mission success.

From a technological perspective, the research confirms that the deployment of airborne DEWs does not require waiting for breakthrough innovations. High-TRL solid-state lasers already provide sufficient capability to deliver meaningful operational effects. The identification of a 30–50 kW class system as a viable “working point” demonstrates that **sufficient capability**, rather than maximum capability, is the key to rapid deployment. This insight challenges traditional development models that prioritize long-term optimization over near-term applicability.

Equally important is the role of **acquisition strategy** in enabling this transformation. The research shows that traditional acquisition processes are incompatible with the urgency of the current threat environment. The adoption of frameworks such as the Middle Tier of Acquisition (MTA) is not simply an efficiency improvement—it is a prerequisite for operational relevance. By enabling rapid prototyping, iterative development, and early fielding, MTA allows the defense community to align technological maturity with operational timelines (GAO, 2023).

The integration of Systemic Operational Design (SOD) principles further reinforces this approach by framing constraints—such as the three-year deployment timeline—not as limitations, but as drivers of innovation. This perspective encourages a shift from risk avoidance to **risk management through iteration**, enabling faster and more adaptive development processes (Graicer, 2017).



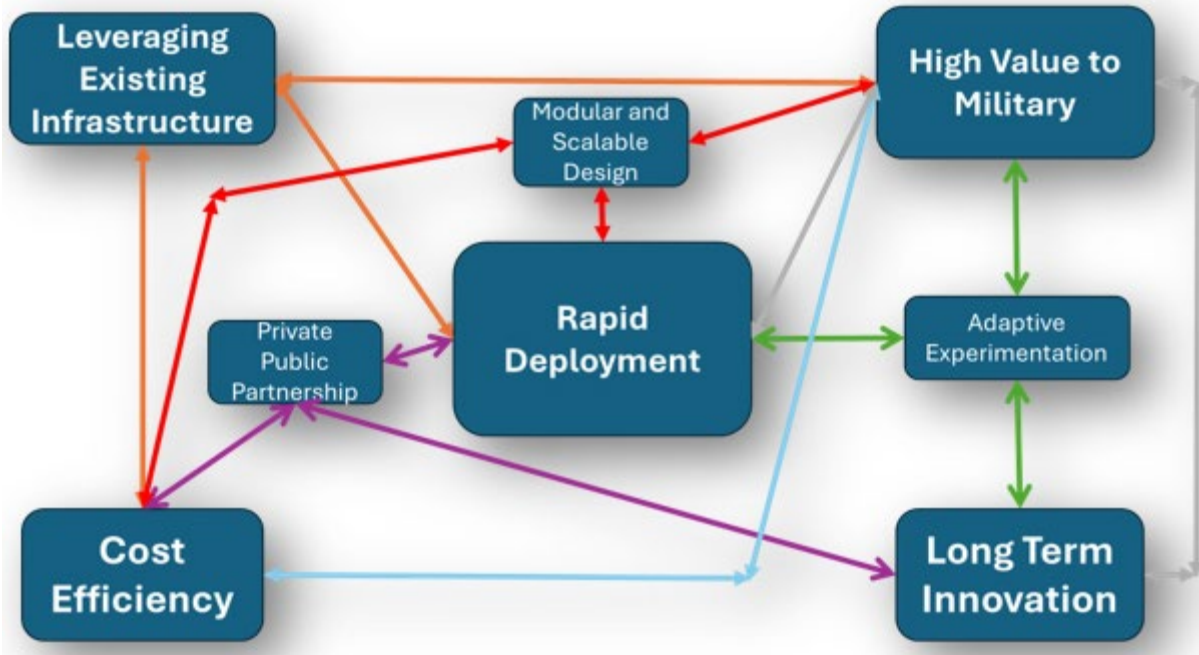


Figure 7: Integrated Strategy for Rapid Deployment and Cost-Effective Defense of DEWs

At the strategic level, the deployment of airborne DEWs signals a broader transition toward **sustainable defense systems**. In an era defined by asymmetric threats and rapid technological change, sustainability becomes a critical factor in maintaining long-term superiority. DEWs contribute to this by reducing logistical burdens, increasing operational endurance, and enabling scalable responses to evolving threats.

However, the successful implementation of airborne DEWs also requires addressing several ongoing challenges. Technical issues related to power generation, thermal management, and beam control must continue to be refined. Operational doctrines must evolve to incorporate DEWs into existing frameworks, ensuring effective coordination with kinetic systems. Regulatory and safety considerations must be carefully managed to prevent unintended consequences, particularly in complex operational environments (Cannin, 2021).

Despite these challenges, the overall conclusion of this research is clear. The rapid deployment of airborne DEWs is both **feasible and strategically necessary**. The convergence of mature technology, evolving threats, and adaptive acquisition frameworks creates a unique opportunity to redefine air defense within a relatively short timeframe.

The implications extend beyond the specific application of DEWs. They reflect a broader lesson for defense innovation: The ability to align technology, operations, and acquisition processes is more critical than any single technological breakthrough. In this context, airborne DEWs serve as a case study in how such alignment can be achieved.

In conclusion, this research demonstrates that a three-year pathway to operational airborne DEWs is realistic, provided that the focus remains on mature technologies, disciplined system design, and accelerated acquisition strategies. More importantly, it shows that the adoption of DEWs has the potential to reshape the future of aerial defense, shifting it toward a model that is more resilient, scalable, and economically sustainable.

The challenge ahead is not whether this transformation is possible—but whether organizations can move fast enough to realize it.

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