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Generating Adaptive Capability from Constraints: Aligning Operational Dependency, Requirements, and Competitive Procurement to Sustain Advantage in Maritime Expeditionary Operations

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Generating Adaptive Capability from Constraints: Aligning Operational Dependency, Requirements, and Competitive Procurement to Sustain Advantage in Maritime Expeditionary Operations

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Abstract

This research examines how infrastructure-driven operational dependency in maritime expeditionary environments can be translated into scalable capability through alignment across dependency identification, requirements development, and competitive procurement. Contemporary operations are constrained by contested logistics, distributed infrastructure networks, and interdependent systems whose performance cannot be assumed, yet existing processes do not effectively convert dependency-driven risk into actionable requirements or generate responsive industrial output at scale.

To address this gap, the research develops an integrated framework linking geostrategic logistics evaluation and nodal selection (GEO-LENS), functionally defined capability requirements, and variable portfolio contracting (VPC). GEO-LENS identifies and prioritizes dependencies using a structured Operational Dependency Index, generating distributed demand signals that are executed through a competitive, multi-vendor procurement model.

Results demonstrate that dependency is concentrated in high-leverage nodes and that energy functions as a system-level pacing constraint. The VPC model improves performance while reducing cost and supply risk by shifting innovation incentives from government-directed processes to continuous competition among firms. These findings demonstrate that constraint, when identified and translated into demand, becomes a driver of adaptability, innovation, and scale—transforming operational vulnerability from a source of risk into a source of advantage.

Background and Problem Statement

The mission was assessed as "low risk":

Within 72 hours, a forward maritime expeditionary force was directed to activate a distributed sustainment network across Europe's high north and eastern flank. Prior planning assumed access to critical infrastructure, including ports in Northern Norway, rail corridors through Sweden and Finland, and logistics hubs extending into the Baltic region. On paper, capacity existed. Contracts were active. Routes were mapped.

Execution revealed reality:

A regional power disruption reduced throughput at a key intermodal hub. Commercial fuel delivery, which was contracted but not prioritized, lagged behind demand. A port remained open but could not sustain offload rates due to power constraints on material handling equipment. Rail movement slowed as competing civilian demand surged. Digital coordination systems remained operational but degraded, forcing manual synchronization across nodes that had never been tested under simultaneous load.

The network did not fail—it revealed constraint.

No single failure stopped operations. Every system functioned—just below the level required. As delays compounded, sustainment timelines slipped beyond operational tolerance.

Commanders were forced to prioritize movement over persistence, trading true sustainment for access.

Background

Strategic advantage in the current security environment is no longer defined solely by the scale of existing capability, but by how accurately the operating environment is understood and translated into capability. Conventional strategy formation emphasizes adversary capability and intent, aligning objectives and resources against external threats while assuming that infrastructure, logistics, and industrial systems will perform as expected. This assumption is fundamentally flawed. In distributed and contested environments, operational outcomes are governed not only by adversary action, but by the performance of interdependent systems that introduce constraint independent of enemy interference. These dependencies shape feasibility, tempo, and persistence, yet remain insufficiently identified and prioritized in planning. Expanding analysis to systematically incorporate operational dependency reframes these constraints as inherent features of the environment, requiring that they be translated into capability before they manifest as operational failure.

The 2025 National Security Strategy (NSS) underscores the need to "evaluate, sort, and prioritize," warning that diffuse prioritization undermines long-term effectiveness. Within this framework, the NSS identifies resilient infrastructure, secure supply chains, and a revitalized industrial and energy base as foundational to sustaining national power, emphasizing that "American national power depends on a strong industrial sector capable of meeting both peacetime and wartime production demands" and calling for "the world's most robust, productive, and innovative energy sector." (Trump, 2025) At the same time, the NSS highlights the strategic consequences of dependency, noting how shifts in global supply chains and energy access have increased reliance on external actors and intensified competition.

The 2026 National Defense Strategy (NDS) translates these priorities into a defense posture defined by simultaneous, multi-theater competition, contested access to key terrain, and the central role of industrial capacity in sustaining operations. This posture prioritizes the ability to defend the homeland, deter aggression, and regenerate combat power at scale, supported by efforts to "reinvest in U.S. defense production, build out capacity, empower innovators, and adopt new advances in technology" (Hegseth, 2026). Together, the NSS and NDS establish a consistent strategic imperative: the ability to generate, project, and regenerate combat power under constraint (through aligned operational, industrial, and resource systems) is central to sustaining advantage.

At the operational level, maritime expeditionary forces are inherently dependent on distributed infrastructure networks to generate, project, and sustain combat power. The Chief of Naval Operations' Fighting Instructions emphasize that naval advantage is produced through the integration of "people, infrastructure, and materiel" within the Foundry—the system that "builds, generates, sustains, and modernizes naval power . . . at the speed and scale necessary to win." This construct reinforces that infrastructure is not a supporting function, but a central component of warfighting effectiveness. Forward naval forces preserve sea lines of communication, enable deterrence, and underpin the economic and logistical flows that sustain national power, operating with "expeditionary reach, unmatched mobility, and persistent presence" in contested environments. In conflict, this dependence intensifies, as the Fleet must "maneuver, strike, and sustain operations across all domains" while absorbing disruption to the very infrastructure upon which it relies (Caudle, 2026).

Similarly, the Commandant of the Marine Corps' Planning Guidance reinforces the requirement for forces to remain forward, distributed, and expeditionary while accounting for the realities of protracted, high-intensity conflict. The guidance emphasizes that "service planning accounts for the significant risk of protraction in a peer versus peer conflict," requiring "sufficient depth of magazine supported by a resilient and distributed logistics network to persist throughout a protracted high-intensity fight." At the same time, it recognizes that the character of war is evolving through extended-range kinetic capabilities and increasingly sophisticated non-kinetic effects across space, cyberspace, and the electromagnetic spectrum, demanding that forces "be increasingly creative" in how they train and operate (Smith, 2024). Together, these priorities reinforce that operational effectiveness depends not only on forward presence, but on the ability to sustain distributed forces through resilient infrastructure and adaptive support systems in contested environments.

These concepts converge on a common operational reality: maritime expeditionary operations are only as effective as the infrastructure networks that enable them. This dependency extends beyond traditional logistics to include energy generation and distribution, maintenance and repair capacity, transportation nodes and access corridors, and the digital and electromagnetic systems required for command and control.

The 2024 Regional Sustainment Framework (RSF) identifies the need to transition from centralized sustainment toward distributed, regionally integrated networks that leverage allies, partners, and industry (LaPlante et al., 2024). While this approach enhances survivability and operational reach, it introduces a critical tension: distribution increases resilience while simultaneously increasing dependence on a wider and more fragile network of infrastructure and supply chains. Operational effectiveness therefore becomes increasingly sensitive to disruptions in access, throughput, sustainment capacity, and enabling resources such as energy.

The Navy Expeditionary Warfighting Development Center's Advanced Naval Basing (ANB) Innovation Forum provides empirical grounding for this tension by identifying early-phase establishment as the period of greatest vulnerability, when assumptions compound and resilience is lowest (Reitter, 2026). The Forum highlights that infrastructure constraints, spread across access, throughput, sustainment, and contractor dependence, do not emerge in isolation but interact to degrade operational feasibility during initial force projection, reinforcing a defining condition:

Constraint, not capacity, defines the operational environment.

Compounding these challenges are structural limitations within defense acquisition and procurement systems. Portfolio Acquisition Executive (PAE) transition memoranda and related reform efforts highlight persistent issues, including slow capability delivery timelines, misalignment between requirements and acquisition outcomes, fragmented decision-making structures, and insufficient adaptability to emerging operational needs (Potter et al., 2025). Although recent reforms emphasize iterative capability development, modular open systems approaches, and improved alignment between requirements and acquisition, the system remains constrained in its ability to translate operational need into scalable industrial response.

Problem Statement

Across strategic guidance, operational doctrine, sustainment frameworks, and acquisition reform efforts, a consistent pattern emerges: operational dependency (defined as the measurable reliance of military operations on the performance and resilience of interconnected infrastructure, logistics networks, and enabling systems, which collectively determine the ability to generate, sustain, and project combat power under constraint) is increasing, yet the ability to translate that dependency into capability remains insufficient. Existing processes do not effectively convert dependency-driven risk into actionable requirements, and procurement systems lack the flexibility and competitive structure necessary to adopt innovations rapidly and generate capability at scale.

Figure 1 depicts the *Spectrum of Operational Dependency*, or the conceptual continuum that defines the range of possible reliance on organic versus external infrastructure, logistics networks, and enabling systems, through which commanders and planners assess and optimize trade-offs between risk, cost, responsiveness, and scalability in order to sustain operational effectiveness under constrained conditions.

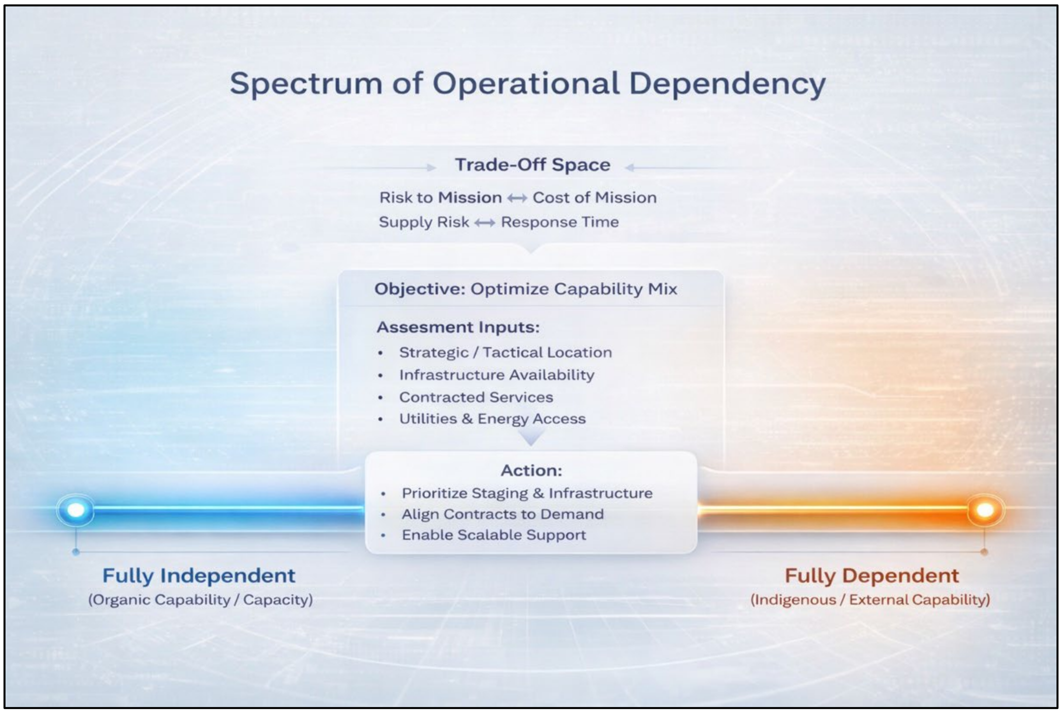

Figure 1. Spectrum of Operational Dependency

Accordingly, the central problem addressed in this research is that the Department of Defense lacks an integrated framework to identify, prioritize, and respond to infrastructure-driven operational dependencies through adaptive capability development and procurement. Without such a framework, constraints imposed by contested environments remain latent until they manifest as operational failure—existing as unidentified and unmanaged risk.

This research addresses that gap by asking:

How can operational dependency, often unmeasured in conventional planning but decisive under contested conditions, be systematically translated into prioritized capability requirements and fulfilled through adaptive, competitive procurement mechanisms?

Scope and Goals

This research examines how operational dependency, often unmeasured in conventional planning but decisive in execution, can be translated into scalable capability through aligned requirements and competitive procurement in maritime expeditionary environments.

The analysis focuses on distributed maritime expeditionary operations conducted in contested environments, where forces rely on a combination of host-nation infrastructure, commercial and dual-use systems, and military-owned capabilities. These environments are characterized by contested access, degraded logistics networks, and limited reliance on centralized sustainment, conditions that amplify infrastructure dependency.

The research centers on infrastructure-driven operational dependency rather than platform-centric limitations. This includes transportation networks, access corridors, sustainment capacity, energy systems, contracted services, and digital infrastructure. These dependencies are treated as measurable and comparable variables through the geostrategic logistics evaluation & nodal selection (GEO-LENS) construct.

The research is bounded to high-quantity, potentially high-attrition operational enablers, such as distributed energy systems, unmanned platforms, sensors, munitions, and expeditionary sustainment assets, where demand is scalable and loss is expected, rather than major defense acquisition programs characterized by low production volume and long development cycles. This reflects the need for scalable, modular, and rapidly fielded capabilities aligned with contested environments (Potter et al., 2025).

Methodologically, the research evaluates an integrated framework consisting of dependency identification (GEO-LENS), requirements translation, and competitive procurement (variable portfolio contracting; VPC).

The research pursues three goals:

1. Identify and prioritize operational dependencies
2. Translate those dependencies into functional requirements
3. Evaluate procurement structures capable of delivering scalable capability under constraint.

Summary of Literature and Foundational Constructs

A growing body of research across defense analysis, infrastructure systems, and industrial strategy converges on a central insight: modern conflict is increasingly defined by contested logistics and infrastructure dependency.

Contemporary operational analysis underscores that logistics has shifted from a supporting function to the decisive factor in great power competition. As Zachary Hughes argues, in conflicts between peer adversaries, “logistics is likely to be the primary determinant of military success or failure,” reframing warfare itself as a contest of “competitive logistics.” While distributed operations enhance survivability, they introduce significant sustainment complexity, particularly when infrastructure is degraded or actively contested. Efforts to mitigate vulnerability, such as dispersion, prepositioning, and push-based resupply impose what Hughes describes as “compounding inefficiencies,” where disruption at any point in the supply chain propagates across the system and degrades overall effectiveness (Hughes, 2024). Under these conditions, logistics is no longer a problem of throughput optimization, but a system-level constraint that governs the feasibility, tempo, and persistence of operations across interconnected nodes.

Infrastructure must therefore be understood not as a collection of independent assets, but as an integrated system whose value emerges from networked interaction. The European Union’s Trans-European Transport Network (TEN-T) provides a practical model for this perspective, emphasizing multimodal integration, interoperability, and the elimination of bottlenecks across a distributed transport architecture. As codified in the 2024 TEN-T regulation, transport infrastructure “functions as a network,” where even the “non-operability of a small segment can hamper the efficiency and competitiveness of the system as a whole” (Publications Office of the European Union [POEU], 2024). This framing shifts the focus from individual node capacity to the performance of connections and flows across the network. Accordingly, system effectiveness is determined not by the strength of isolated assets, but by the resilience and coherence of their interactions. This systems-based understanding aligns directly with the GEO-

LENS construct, which evaluates infrastructure as a network of interdependent capabilities whose collective performance defines operational feasibility.

The NEXWDC Advanced Naval Basing Innovation Forum provides empirical validation of these theoretical constructs. The Forum demonstrated that distributed basing concepts are most vulnerable during early establishment phases, when infrastructure is incomplete and resilience is lowest. It identified multiple interdependent constraints, including access limitations, throughput restrictions, sustainment capacity gaps, contractor reliance, and digital infrastructure vulnerabilities. These constraints do not operate independently; they interact in ways that compound risk and reduce operational effectiveness. The Forum further highlights that energy and energy control systems function as system-enabling dependencies, shaping the performance of all other operational functions (Reitter, 2026).

The RSF reinforces a fundamental shift from centralized sustainment toward a “globally connected, resilient . . . ecosystem” built on distributed, collaborative networks that integrate allies, partners, and the defense industrial base. Rather than relying on traditional models that retrograde materiel to centralized locations, the framework emphasizes positioning maintenance, repair, and sustainment capabilities “closer to the point of need” within a network of geographically dispersed nodes (LaPlante et al., 2024). This transition enhances survivability, responsiveness, and operational flexibility in contested logistics environments, but it also expands the number of critical dependencies across infrastructure, industrial capacity, and partner-enabled supply chains. As sustainment becomes distributed, the system’s performance is increasingly determined by the interaction of these nodes rather than any single capability. Consequently, operational effectiveness becomes more sensitive to disruption, reinforcing the requirement for analytical approaches that can identify, prioritize, and manage dependency across interconnected networks—an imperative directly addressed by the GEO-LENS construct.

At the national level, analysis of the defense industrial base reveals a structural misalignment between operational demand and industrial capacity. Contemporary supply chains remain optimized for efficiency and cost minimization rather than surge production and sustained wartime output, limiting their ability to respond to rapid increases in demand. As highlighted in Revitalizing National Security Supply Chains, the “DoD faces a disconnect between its operational planning and its industrial planning,” a gap that constrains the nation’s ability to translate requirements into deliverable capability at scale (Attar et al., 2025). This misalignment is compounded by insufficient integration across government, industry, and allied partners, as well as limited visibility into real-time demand signals and production capacity. Without a coherent mechanism to generate, communicate, and sustain demand signals, industrial systems cannot effectively align investment, workforce, or production decisions to operational needs. The result is a system in which demand consistently outpaces capacity under contested conditions, reinforcing the requirement for frameworks that can translate operational dependency into actionable requirements and align procurement structures to drive responsive, scalable industrial output.

The Department of Defense’s Office of Strategic Capital (OSC) reinforces the central role of private capital, market competition, and financial incentives in scaling national security capability. Rather than relying solely on government-directed investment, the OSC framework recognizes that “private markets continue to finance most investments” in critical technologies and industrial capacity, making engagement with private firms essential to generating competitive advantage (Austin, 2025). This perspective reframes industrial responsiveness as a function of capital flows, risk-adjusted returns, and competitive positioning across economic networks, key industries, and critical technologies. As detailed in the FY2025 Investment Strategy, strategic competition increasingly unfolds within capital markets themselves, where investment decisions shape long-term industrial capacity and technological leadership.

Consequently, procurement and investment mechanisms must do more than acquire capability; they must actively influence industrial behavior by structuring incentives, shaping competition, and directing capital toward priority outcomes. This shift underscores a critical requirement: the design of procurement systems must align with market dynamics to mobilize private investment, accelerate production scaling, and sustain competitive advantage in contested environments.

Taken together, these bodies of work establish several foundational conditions. Operational effectiveness is increasingly constrained by infrastructure and logistics systems. These constraints are systemic and interdependent, often propagating across networks rather than remaining localized. Existing processes do not consistently translate dependency-driven risk into actionable requirements, and procurement systems are not structured to respond to those requirements at the speed and scale required.

These findings define the foundational requirement for this research:

A framework is required to identify operational dependencies, translate them into capability requirements, and align procurement mechanisms to deliver scalable capability under constraint.

Conceptual Framework

This research proposes a framework that transforms operational dependency into capability through alignment across three functions: dependency identification, capability requirements, and competitive procurement. Rather than treating capability development as a linear acquisition process, the framework defines it as a system in which operational conditions generate demand, and aligned mechanisms produce capability in response.

The GEO-LENS construct, provides the dependency identification function. GEO-LENS evaluates geographic nodes and infrastructure systems using the Operational Dependency Index (ODI), which incorporates factors such as infrastructure capacity, access, utilities, supply chains, governance, digital systems, environmental conditions, and threat exposure. These factors are normalized and combined to produce comparative assessments of nodes within a distributed network. The output is a prioritized set of dependencies expressed in terms of node-level risk, contribution to operational objectives, and interdependence with other nodes.

Within this framework, GEO-LENS defines where and why capability is required. It does not prescribe solutions; instead, it establishes the operational conditions that generate demand. This distinction is critical, as it ensures that capability development is driven by dependency rather than pre-determined solutions.

Capability requirements serve as the translation mechanism between dependency identification and procurement execution. Requirements convert identified dependencies into functional descriptions of what capabilities must achieve to mitigate operational risk. In this framework, requirements are expressed in terms of operational effects (such as enabling throughput, sustaining operations, maintaining survivability, or supporting command and control) rather than specific technical configurations. This approach enables modularity, scalability, and adaptability, allowing multiple technical solutions to satisfy operational demand.

The structure of requirements directly influences the effectiveness of procurement. Functionally defined requirements create clear demand signals that can be addressed by a range of industrial providers, while overly prescriptive requirements constrain competition and limit adaptability. As such, requirements function as the central mechanism through which operational dependency is translated into actionable industrial demand.

Competitive procurement, implemented through variable portfolio contracting, provides the execution function. The VPC model engages multiple vendors simultaneously and allocates production dynamically based on cost, schedule, and performance. This structure maintains continuous competition, incentivizes improvement, and distributes production across multiple providers. By avoiding reliance on a single supplier, it reduces supply risk and enables surge capacity.

Within the framework, procurement is not a passive mechanism for acquiring capability but an active tool for shaping industrial behavior. The ability to adjust allocation based on performance creates a feedback loop in which industrial output evolves in response to operational demand signals and competition between contracted firms.

The interaction of these three elements forms a capability pipeline (depicted in Figure 2).

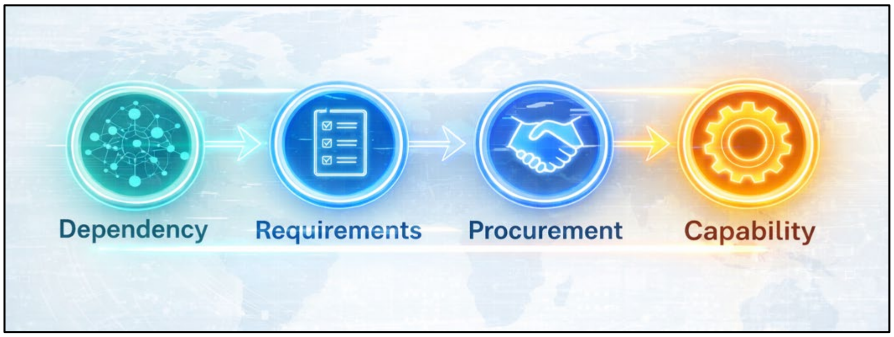

Figure 2. Aligned Capability Pipeline

Alignment across this system determines outcomes. When dependency identification accurately reflects operational conditions, requirements translate those conditions into clear demand signals, and procurement enables responsive industrial execution, the system produces scalable and adaptive capability. When misaligned, the system produces delays and inefficiencies which translate to increased operational risk.

This framework establishes that capability is not assumed. It is produced through the alignment of systems operating under constraint.

The interaction of dependency identification, requirements development, and procurement execution establishes a system in which operational conditions generate demand and aligned mechanisms produce capability. Within this system, the role of each component is distinct but interdependent.

GEO-LENS provides a structured method for identifying and prioritizing dependencies across a distributed infrastructure network. By evaluating nodes against operational objectives and constraint factors, it produces a prioritized set of dependencies that define where capability is required and the relative importance of those requirements. Importantly, this output reflects both individual node performance and the interdependence of nodes within the broader system.

Requirements translate these prioritized dependencies into functional demand signals. This translation is not a direct mapping of infrastructure limitations to technical solutions; rather, it defines the operational effects required to mitigate risk. By focusing on function rather than form, requirements enable multiple pathways to capability development and support adaptability as conditions evolve (Pierce, 2025).

Procurement executes these requirements through competitive mechanisms designed to align industrial behavior with operational demand. Within the VPC construct, multiple vendors compete continuously across cost, schedule, and performance dimensions. Allocation of production is adjusted dynamically, ensuring that industrial output reflects both demand signals and contractor performance. This structure reduces reliance on single providers, increases resilience, and enables scalable production (Pierce, 2025).

A critical implication of the VPC model is the shift in innovation incentives from the government to the industrial base. Under traditional contracting structures, innovation is largely government-directed, requiring predefined requirements, dedicated funding, and extended development timelines. In contrast, the VPC structure creates continuous post-award competition in which firms gain or lose production share based on cost, schedule, and performance outcomes. This dynamic incentivizes firms to independently invest in process improvements, production efficiency, and technological innovation in order to increase competitiveness. As a result, innovation becomes decentralized, self-funded, and continuous, rather than episodic and government-driven. This shift not only accelerates the incorporation of innovation into operational capability, but also aligns industrial investment with operational demand signals, reinforcing the adaptability and scalability of the procurement system.

The system is inherently iterative. Changes in operational conditions alter dependency assessments, which in turn adjust requirements and influence procurement decisions. Similarly, industrial performance feeds back into procurement allocation, shaping future production capacity and capability outcomes. This feedback loop ensures that capability development remains responsive to changing conditions rather than fixed at a single point in time.

The framework therefore establishes capability generation as a dynamic process driven by alignment:

Dependency identification defines demand; requirements structure that demand; procurement delivers capability at scale.

Methodology

This research employs a structured, two-phase experimental design to evaluate the effectiveness of the proposed framework. The design separates dependency identification from procurement execution, allowing independent assessment of decision-making processes and industrial response. This separation enables analysis of both individual components and the effects of alignment across the system.

Operational Scenario and Analytical Context

Area of Operations (AO)

The experiment is conducted within a contested maritime expeditionary environment spanning Northern Europe (incorporating Arctic logistics corridors, Baltic and Northern European nodes) and Black Sea and Eastern Mediterranean access points, capturing a region characterized by dense infrastructure networks, strategic chokepoints, and exposure to real-world geopolitical constraints.

This AO is selected because it:

- Contains interdependent infrastructure systems (ports, rail, energy, logistics nodes)
- Reflects operationally relevant geopolitical friction
- Introduces scarcity across access, throughput, and sustainment functions

Within this environment, infrastructure operates simultaneously as an enabler and a constraint. Operational effectiveness is therefore dependent on network performance rather than isolated node capacity.

Strategic and Threat Context

The scenario incorporates a competitive environment defined by a near-peer adversary, the Russian Federation, whose strategic posture introduces friction across the same infrastructure systems required for maritime expeditionary operations.

Adversary effects are represented across four primary vectors:

- Infrastructure contestation: disruption or degradation of ports, rail, energy, and repair nodes
- Arctic leverage: control of northern maritime routes and energy access
- Black Sea access denial: constraints on maritime throughput and sustainment
- Industrial endurance: sustained operations under attrition and sanction conditions

This context aligns with the National Defense Strategy's identification of Russia as a persistent threat across the Eastern Flank, Arctic, and Black Sea regions.

Strategic Objectives

The experiment is structured around three prioritized strategic objectives, providing the basis for evaluating infrastructure dependency and capability demand across the operational network:

1. Preserve NATO freedom of action on the Eastern Flank
2. Deny adversary leverage over Arctic and High North access
3. Limit adversary ability to sustain protracted conflict through industrial and energy pressure

Time Horizon

The experiment is conducted over a 36-month period (February 1, 2026–January 31, 2029), a duration enables observation of both short-term friction and longer-term system behavior:

- Initial establishment under constrained conditions
- Evolution of infrastructure dependency over time
- Contractor performance and adaptation
- Procurement reallocation effects

Phase I: Dependency Identification and Prioritization (GEO-LENS)

Phase I applies the GEO-LENS model to identify and prioritize infrastructure-driven dependencies. A set of operational nodes is selected based on geographic relevance, infrastructure diversity, and contribution to strategic objectives.

A set of geographically distributed nodes is defined to represent key infrastructure within the operational environment. These nodes include ports, airfields, logistics hubs, rail corridors, and regional sustainment and energy systems, including (depicted in Figure 3):

- Central Europe Transit Corridor: Ostrava–Žilina–Budapest (overland logistics corridor)
- Baltic Region: Klaipėda Port; Riga Logistics Hub
- High North / Arctic: Narvik Port; Bodø Air & Multimodal Node; Luleå Intermodal Hub; Oulu Sustainment Center
- Black Sea: Varna Port
- Eastern Mediterranean: Alexandroupoli Port

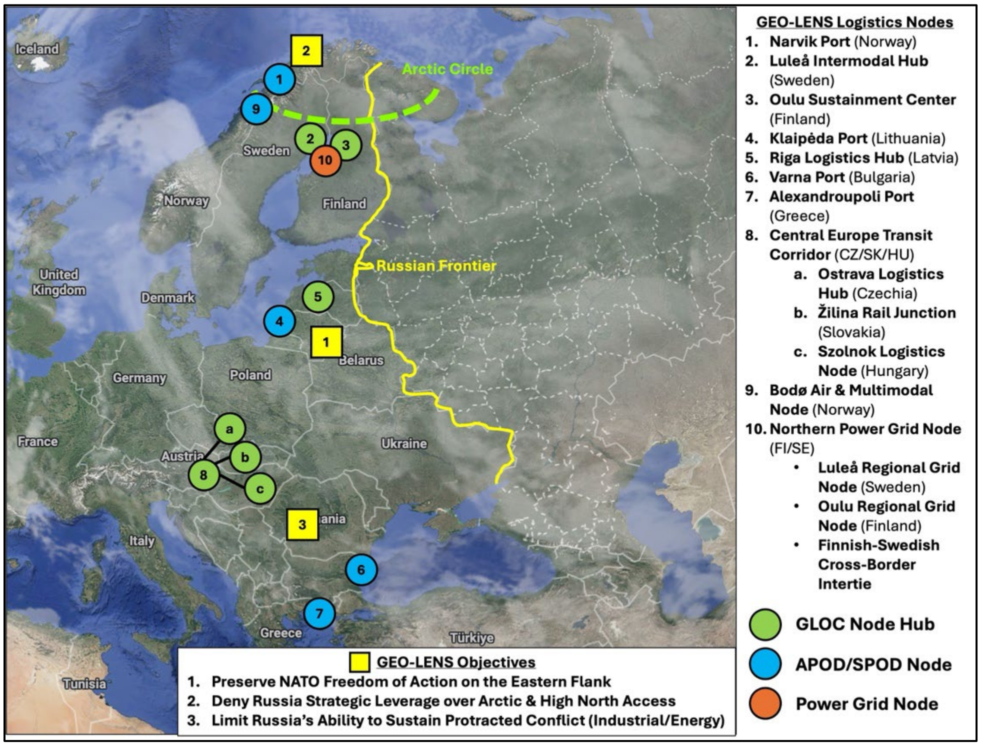

Figure 3. GEO-LENS Nodes and Objectives

Each node is evaluated using the Operational Dependency Index (ODI), which incorporates a standardized set of assessment factors, which are normalized and aggregated to produce node-level dependency scores, enabling comparison across the network:

- Infrastructure capacity and transportation networks
- Utilities and energy availability
- Supply chains and contracted services
- Governance and regulatory environment
- Digital and command and control (C2) systems
- Environmental and climate factors
- Threat exposure

The ODI inputs (generated from United States Army Corps of Engineers Theater Infrastructure Framework and Country Profile documents and open-source information) are normalized and processed within the GEO-LENS model to produce node-level dependency scores. The model evaluates nodes relative to defined strategic objectives and generates a prioritized set of infrastructure nodes. In addition to prioritization, the model produces a resource-constrained synchronization matrix that identifies the sequencing and coordination of actions required to support operational objectives.

The output of Phase I is a structured representation of operational dependency, expressed in terms of prioritized nodes, identified constraints, and associated risk. This output defines where capability is required but does not prescribe how that capability should be delivered.

Requirements Translation: From Dependency to Demand

Following dependency identification, GEO-LENS outputs are translated into capability requirements. This process converts identified constraints into functional descriptions of what capabilities must achieve to mitigate operational risk.

Requirements are expressed in terms of operational effects rather than technical specifications. These effects include enabling throughput across constrained transportation networks, sustaining operations at distributed nodes, maintaining survivability in degraded environments, and supporting C2 functions under contested conditions. This approach ensures that requirements remain adaptable and do not constrain solution space unnecessarily.

The translation process produces a demand signal characterized by three key attributes. First, it is distributed, reflecting the geographic dispersion of prioritized nodes. Second, it is scalable, allowing capability quantity and allocation to adjust based on operational conditions. Third, it is modular, enabling multiple technical solutions to satisfy the same functional requirement.

This demand signal provides the basis for procurement execution in Phase II.

Phase II: Competitive Procurement and Industrial Response (VPC)

Phase II applies the VPC model to simulate industrial response to the demand signal generated in Phase I. The VPC model is designed to evaluate how procurement structure influences capability delivery under conditions of competition and uncertainty.

A set of contractors is defined, each characterized by production rate, unit cost, and performance attributes (depicted in Figure 4). These contractors represent heterogeneous industrial actors with varying capabilities and constraints. Production is allocated across contractors simultaneously, rather than through a single-award structure.

Figure 4. VPC Contractor Rating Calculator

Allocation decisions are based on cost, schedule, and performance metrics. As contractors perform over time, their relative performance influences future allocation, creating a dynamic system in which market share shifts in response to demonstrated capability. This structure sustains competition and incentivizes continuous improvement.

The model incorporates variability in contractor performance, reflecting changes in production efficiency, supply chain conditions, and operational disruptions. These dynamics enable assessment of how procurement structures respond to uncertainty and how they influence supply resilience and scalability.

The VPC model is implemented within a structured analytical environment that tracks contractor performance, allocation decisions, and capability delivery over time. This allows for comparative analysis across different weighting schemes, including even-weighted, cost-weighted, schedule-weighted, and performance-weighted allocation strategies.

Integration of Phases

The two phases are integrated through the linkage between dependency identification, requirements translation, and procurement execution. GEO-LENS outputs define where capability is required, requirements translate those needs into demand signals, and VPC execution determines how effectively those signals are fulfilled.

This integration enables evaluation of the central thesis: that Constraint becomes a driver of capability when operational dependencies are translated through aligned requirements and fulfilled through competitive procurement, producing measurable improvements in capability outcomes.

Evaluation Criteria

The effectiveness of the framework is assessed across four dimensions. Decision quality is evaluated based on the ability of GEO-LENS to identify and prioritize meaningful dependencies. Procurement adaptability is assessed through the responsiveness of the VPC model to changes in contractor performance. Supply resilience is measured by the ability to maintain production under variability and disruption. Capability outcomes are evaluated in terms of performance, cost, and delivery over time.

These criteria provide a comprehensive assessment of how alignment across the framework influences the generation of capability under constraint.

Results and Analysis

GEO-LENS Outputs: Dependency Prioritization

Application of the GEO-LENS model produced a prioritized set of infrastructure nodes aligned to defined strategic objectives within the European operational environment. The results demonstrate that operational dependency is not evenly distributed across the network, but instead concentrated within a limited number of high-leverage nodes whose performance directly enables access, throughput, sustainment, and network integration.

Across multiple strategic objectives, GEO-LENS consistently identified Klaipėda Port and the Central Europe Transit Corridor as repeat selections, indicating that these nodes function as theater-critical infrastructure. Their capacity and resilience enable NATO reinforcement of the Eastern Flank while simultaneously constraining adversary sustainment under protracted conflict conditions. This convergence highlights that certain nodes are not only important, but disproportionately decisive within the operational system.

Beyond individual prioritization, the model reveals that infrastructure operates as an interconnected system organized into complementary geographic and functional clusters. Three primary infrastructure groupings emerge:

- Baltic / Eastern Flank Cluster: Klaipėda Port, Riga Logistics Hub, Central Europe Transit Corridor
- High North / Arctic Cluster: Narvik Port, Oulu Sustainment Center, Bodø Multimodal Node
- Southern Access Cluster: Alexandroupoli Port

These clusters demonstrate that operational effectiveness depends on coordinated performance across distributed, multimodal nodes. Degradation or constraint at a single node propagates across the network, reducing overall system effectiveness. As a result, infrastructure must be evaluated collectively rather than as isolated assets.

The GEO-LENS outputs establish two defining conditions. First, operational dependency is concentrated within specific nodes and network clusters rather than distributed uniformly. Second, the value of these nodes is derived not only from individual capacity, but from their role within a system of interdependencies. Operational effectiveness is therefore governed by network performance, reinforcing the requirement to prioritize resilience and capacity across interconnected infrastructure systems rather than optimizing individual nodes in isolation.

Constraint Identification Across Infrastructure Systems

The translation of GEO-LENS outputs into operational analysis revealed a range of infrastructure-driven constraints that shape the feasibility of maritime expeditionary operations. These constraints include transportation throughput limitations, access restrictions, sustainment capacity gaps, contractor and labor dependencies, and vulnerabilities in digital and C2 infrastructure.

Transportation constraints were observed in multimodal corridors and logistics hubs where port offload rates, rail capacity, and transfer efficiency limited the movement of materiel. Access constraints emerged from a combination of geographic, political, and regulatory factors that affected the ability to utilize infrastructure in contested or uncertain environments. Sustainment constraints reflected uneven distribution of maintenance and repair capabilities, particularly at forward nodes where capacity to preserve operational readiness is limited. Contractor dependence introduced variability in labor availability and scalability, while digital infrastructure vulnerabilities affected coordination, information flow, and C2 effectiveness.

These constraints did not manifest uniformly across all nodes. Instead, their impact varied based on geographic location, infrastructure maturity, and operational context. Some nodes were primarily limited by throughput, while others were constrained by access or sustainment capacity. This variation reinforces the need for structured analysis to identify and prioritize constraints rather than relying on generalized assumptions.

Constraint Convergence: Energy as the System-Level Driver

While multiple constraints influenced operational performance, analysis across all prioritized nodes revealed a consistent pattern of convergence around a single dependency. Energy availability emerged as a cross-cutting constraint affecting all operational functions and infrastructure nodes within the system.

Energy underpins transportation throughput by enabling port operations, material handling equipment, and logistics networks. It supports sustainment by powering maintenance, repair, and life-support systems at distributed nodes. It enables C2 functions through digital and communication infrastructure. It is also essential for survivability, particularly in austere or degraded environments where external support is limited.

Unlike other constraints, which varied in significance across nodes, energy consistently influenced the effectiveness of all operational functions. This convergence indicates that energy functions as the system-level pacing constraint governing the performance of the broader infrastructure network. While other constraints shape operational risk in localized or context-specific ways, energy defines the baseline conditions under which all other capabilities operate.

This finding aligns with empirical observations from the Advanced Naval Basing Innovation Forum, which identified energy and energy control systems as foundational to distributed operations. More broadly, it reinforces the principle that constraint convergence, rather than isolated limitation, determines system-level performance.

Requirements Formation: Translating Constraint into Demand

The identification of convergent constraints enabled the development of a structured demand signal through requirements translation. By expressing requirements in functional terms, the analysis converted infrastructure-driven dependencies into capability needs aligned with operational conditions.

The resulting demand signal exhibited three defining characteristics. First, it was distributed, reflecting the geographic dispersion of prioritized nodes and infrastructure clusters. Second, it was scalable, allowing capability quantity and allocation to adjust based on operational tempo and resource availability. Third, it was modular, enabling multiple technical solutions to satisfy functional requirements without constraining innovation.

These characteristics ensure that requirements capture operational need without prescribing specific technical solutions. This approach expands the solution space available to industry and supports adaptability as conditions evolve. More importantly, it establishes requirements as the mechanism through which dependency is translated into actionable demand.

Competitive Procurement Outcomes: Variable Portfolio Contracting

Application of the VPC model to the generated demand signal produced consistent improvements across performance, cost, and scalability metrics. Across multiple allocation strategies (cost-weighted, schedule-weighted, performance-weighted, and balanced models) the results demonstrate that competitive, multi-vendor procurement can simultaneously enhance capability performance while reducing cost.

Performance outcomes improved across all models, with capability performance increasing by approximately 3.9% to 4.1% relative to baseline conditions. Concurrently, average unit costs decreased by approximately 0.47% to 1.04%, while average contract costs declined by approximately 1.05% to 1.22% (depicted in Table 1). These results indicate that performance improvement and cost efficiency are not mutually exclusive under competitive procurement conditions, but can be achieved concurrently through structured competition.

Table 1. VPC Performance Metrics

Beyond aggregate performance gains, the VPC model reveals distinct patterns in industrial behavior driven by allocation strategy. Under cost- and schedule-weighted models, production tends to concentrate among high-efficiency contractors, yielding lower unit costs (approximately \$208,000–\$209,000) but producing wider contract value distributions (approximately \$8.7 million–\$20.1 million). This concentration improves efficiency but increases reliance on a smaller subset of suppliers. In contrast, performance-weighted allocation produces a narrower contract value range (approximately \$13.4 million–\$15.8 million), sustaining a broader base of active suppliers and reducing concentration risk. Balanced allocation strategies provide a compromise between these outcomes, maintaining competition while preserving cost discipline (all depicted in Table 2).

Table 2. VPC Contract Comparison

These results demonstrate that procurement structure directly influences both industrial behavior and system resilience. By maintaining multiple active suppliers and dynamically adjusting allocation based on cost, schedule, and performance, the VPC model reduces supply risk, sustains competition, and enables scalable production capacity. Importantly, minimum contract values across all models remain sufficiently large to incentivize firms to invest in production tooling, workforce development, and capability improvement, reinforcing long-term industrial responsiveness.

Collectively, the VPC outputs confirm that portfolio-based procurement not only improves acquisition outcomes, but also shapes the industrial base in ways that enhance both efficiency and resilience under conditions of sustained demand and uncertainty.

Integrated Analysis: Alignment as the Determinant of Outcome

The combined results of GEO-LENS, requirements translation, and competitive procurement demonstrate that alignment across these elements determines whether constraint produces capability or operational risk. Each component performs a distinct function within the system, but their effectiveness depends on how they interact.

GEO-LENS defines the operational conditions by identifying and prioritizing dependencies. Requirements translate those conditions into structured demand signals that reflect operational need. Procurement executes those signals by shaping industrial response through competitive mechanisms. When aligned, these elements form a coherent system that produces scalable and adaptive capability.

Misalignment at any stage disrupts this process. If dependencies are not accurately identified, requirements fail to capture true operational need. If requirements are poorly structured, demand signals become unclear or overly restrictive. If procurement mechanisms are rigid or concentrated, industrial response cannot scale effectively. In each case, the result is delayed capability delivery and increased operational risk.

The results therefore validate the central thesis of this research.

Constraint becomes a driver of capability when operational dependencies are translated through aligned requirements and fulfilled through competitive procurement, producing measurable improvements in capability outcomes.

This reframes constraint from a limiting condition to a generative input. Under this framework, the presence of constraint does not reduce capability; rather, it defines the conditions under which capability must be produced. The ability to identify, translate, and align responses to those constraints determines operational advantage.

Summary of Key Findings

The results yield several key findings. Infrastructure dependency is concentrated in high-leverage nodes and networks rather than distributed evenly. Multiple constraints shape operational performance, but their impact varies across nodes. Energy availability consistently emerges as the system-level pacing constraint affecting all operational functions. Requirements serve as the critical bridge between dependency identification and industrial response. Procurement structure shapes industrial behavior, influencing both efficiency and resilience. Finally, alignment across dependency, requirements, and procurement determines whether capability is generated effectively under constraint.

Conclusion and Recommendations

Conclusion

This research examined how infrastructure-driven operational dependency and vulnerability—often unmeasured in conventional planning but decisive in execution—can be translated into scalable capability through the alignment of dependency identification, requirements development, and procurement execution. The findings demonstrate that generating capability under constraint is not a function of existing capacity alone, but of how effectively dependency is identified, prioritized, and converted into actionable demand and responsive industrial output.

First, the application of GEO-LENS confirmed that infrastructure dependency can be systematically identified, measured, and prioritized within a distributed operational environment. The model demonstrated that dependency is concentrated within a limited number of high-leverage nodes and networks, and that operational effectiveness is governed by the performance of these interconnected systems rather than individual infrastructure elements.

Second, the translation of these dependencies into functional capability requirements established a clear mechanism for converting operational conditions into structured demand signals. By defining requirements in terms of operational effects rather than technical specifications, the framework enables adaptability, scalability, and competition, ensuring that capability development remains aligned with evolving conditions.

Third, the application of the VPC demonstrated that procurement structure directly influences capability outcomes. Competitive, multi-vendor procurement reduced supply risk, improved performance, and maintained cost discipline while enabling scalable production. These results confirm that procurement is not a passive mechanism for acquiring capability, but an active tool for shaping industrial behavior and aligning production with operational demand.

Taken together, these findings support the central conclusion of this research.

Adaptive capability is generated through alignment across dependency identification, requirements development, and competitive procurement under conditions where constraint, not capacity, defines the operational environment.

This conclusion reframes constraint from a limiting factor to a defining input. Rather than reducing capability, constraint establishes the conditions that drive demand and shape effective responses. The ability to identify, translate, and align responses to constraint determines whether operational systems produce capability or experience degradation.

Limitations

Several limitations should be considered when interpreting the results of this research:

The experimental design relies on modeled environments, including GEO-LENS dependency assessments and VPC-based procurement simulations. While these models provide structured and repeatable analysis, they do not fully capture the variability and complexity of real-world operational and industrial systems. Contractor behavior, supply chain dynamics, and regulatory constraints may differ in practice.

The VPC model simplifies elements of acquisition, including funding timelines, contract negotiation processes, and regulatory requirements. Although the model is designed to reflect competitive dynamics, its implementation within existing acquisition frameworks would require further validation and adaptation.

The accuracy of GEO-LENS outputs is dependent on the quality and completeness of input data. Variability in data sources or assessment assumptions may influence prioritization outcomes, particularly when applied across different geographic regions or operational contexts.

Additionally, the research focuses on a specific operational environment and a bounded set of capability requirements. While the framework is designed to be broadly applicable, further testing is required to assess its effectiveness across different theaters, mission sets, and capability categories.

Despite these limitations, the methodology provides a consistent and analytically rigorous basis for evaluating the relationship between dependency, requirements, and procurement. It enables controlled assessment of how alignment across these elements influences capability generation under constrained conditions.

Recommendations for Future Research, Modeling, and Testing

To expand the applicability of the framework and address identified limitations, future research should extend GEO-LENS analysis to additional operational environments, particularly within the Indo-Pacific, where geographic dispersion, infrastructure variability, and operational distances introduce additional complexity. Exploration of a distributed infrastructure architecture analogous to the Trans-European Transport Network, adapted for Indo-Pacific conditions, would provide valuable insight into large-scale network design.

Modeling efforts should incorporate dynamic adversary behavior and real-time disruption scenarios to better capture the evolution of infrastructure dependency under contested conditions. Integration of industrial base data (including production capacity, supply chain dependencies, and labor constraints) would improve the fidelity of both dependency assessment and procurement simulations.

Additional experimentation should apply the framework across a broader range of capability categories, including unmanned systems, logistics throughput enablers, and sustainment capabilities. Comparative analysis across these categories would help validate the generalizability of the framework and identify category-specific dynamics.

Field-based validation is also required. The framework should be incorporated into exercises, war games, and operational planning efforts to evaluate its effectiveness under real-world conditions, including the integration of dependency analysis into planning processes, the development of functional requirements, and the responsiveness of procurement mechanisms.

Future research should also advance program-based or web-enabled implementations of GEO-LENS and VPC that leverage artificial intelligence and Internet of Things (IoT)-enabled data streams to enable real-time or near-real-time assessment and procurement adaptation. These systems would ingest live data from infrastructure, logistics networks, energy systems, contractor production lines, and commercial supply chains to continuously update Operational Dependency Index scoring, dynamically refine requirements, and adjust contract allocation across vendors based on evolving cost, schedule, and performance conditions.

AI-enabled analytics and machine learning models could identify emerging constraint patterns, forecast disruption risk, and recommend allocation shifts within the VPC construct, transforming the framework from a periodic analytical tool into a continuously adaptive decision system. Future modeling and field experimentation should evaluate the feasibility, security, and decision advantage of these architectures within contested environments, including integration with joint command-and-control systems, resilience under degraded or denied communications, and the implications of automated or human-in-the-loop contract reallocation.

Finally, pilot programs should be conducted to test portfolio-based procurement structures and AI-enabled GEO-LENS/VPC implementations within operational acquisition environments. These pilots would provide empirical data on contractor behavior, performance outcomes, supply resilience, and the effectiveness of real-time adaptive decision systems, enabling continuous alignment between operational dependency, requirements, and procurement execution at operationally relevant speeds.

Recommendations for Action

The findings of this research have immediate implications for the military, the acquisition community, the defense industrial base, and the research community. While long-term reform will require sustained effort, several near-term actions can be taken to address the identified challenges.

Military organizations must integrate structured dependency analysis into operational planning and treat infrastructure as a pacing function rather than a supporting consideration. In contested environments, infrastructure performance governs the feasibility, tempo, and persistence of operations; failure to explicitly account for dependency risks results in plans that are optimized for conditions that will not exist in conflict. Exercises and war games must therefore incorporate infrastructure degradation, contested access, and sustainment constraints as primary variables. This requires accepting increased planning complexity and near-term reductions in perceived readiness in order to expose vulnerabilities early and avoid operational failure at scale.

Acquisition and procurement organizations must transition from static, single-award contracting toward portfolio-based procurement models capable of responding to distributed and evolving demand. Pilot programs should focus on high-quantity, scalable capabilities where competition can be sustained over time. Requirements development must prioritize functional performance, modularity, and scalability to enable continuous competition and adaptation. This shift requires accepting near-term inefficiencies, reduced predictability in contract outcomes, and increased management complexity in order to reduce long-term supply risk, accelerate innovation, and generate resilient, surge-capable industrial capacity.

The defense industrial base must transition from efficiency-optimized production models to flexible, surge-capable systems designed to respond to distributed and evolving demand signals generated by operational dependency. Under competitive procurement structures, firms no longer compete to win contracts; they compete to retain and expand production share. Allocation is continuously adjusted based on cost, schedule, and performance outcomes, creating a selection environment in which adaptability determines survival. Firms that fail to invest in scalable production, resilient supply chains, and rapid reconfiguration capability will lose relevance as demand shifts. In this system, adaptability is not an advantage—it is a requirement for participation.

The academic and research community must expand interdisciplinary efforts linking operational analysis, infrastructure systems, supply chains, and industrial economics to support the development of analytically rigorous and operationally relevant frameworks. This includes advancing modeling approaches, validation methods, and data integration techniques that can capture dynamic, contested environments. Such work requires moving beyond domain-specific optimization toward integrated system analysis, accepting increased methodological complexity and uncertainty in order to better represent real-world conditions and inform decision-making under constraint.

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