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DISTRIBUTED INTELLIGENCE AT THE TACTICAL EDGE: ENABLING CONTESTED LOGISTICS IN DEGRADED NETWORKS

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ABSTRACT

Contested logistics environments expose the limitations of both legacy fragmented systems and emerging Next Generation Command and Control architectures that assume persistent connectivity. In degraded or denied conditions, sustainment operations face latency, bandwidth constraints, and reduced decision velocity. Expanded decision support tools further increase reliance on timely, relevant data exchange. This paper argues that contested logistics requires distributed, mission-aware intelligence at the tactical edge. Low-power onboard compute enables real-time inference, adaptive data conditioning, and connectivity-aware transmission across Radio-Frequency and non-RF pathways. By selectively elevating critical information based on mission context and network state, edge-intelligent architectures improve survivability, bandwidth efficiency, and sustainment effectiveness in degraded networks.

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1. INTRODUCTION

Modern ground formations are increasingly dependent on digital systems to generate, move, and act upon logistics information in near real time. Vehicle telemetry, predictive maintenance analytics, condition-based sustainment models, and digital supply chain integration have expanded the volume and velocity of data required to support operational decision-making. The adoption of a common contingency framework employing progressively degraded methods, organized as Primary, Alternate, Contingency, and Emergency (PACE), is critical to maintaining operational continuity. A well-defined PACE plan helps prevent information loss, communication breakdowns, and decision paralysis during disruptions, ensuring the initiative can continue to operate effectively under degraded conditions. A LogPACE Communications/Data Plan defines the communications and data architecture that supports logistics operations across a complex and dynamic operational environment. The plan establishes how logisticians, maintenance personnel, supply teams, and commanders will exchange information, in prioritized order, when primary communication or data-sharing methods become unavailable.

Initiatives such as LogPACE [8] seek to accelerate logistics decision velocity through digital integration and data-informed sustainment processes. However, as sustainment architectures become more data-centric, they also become more dependent on reliable, persistent communications pathways.

The operational environment, particularly in Large-Scale Combat Operations (LSCO) against peer adversaries, challenges the assumption of persistent connectivity. Electromagnetic spectrum congestion, electronic warfare, cyber disruption, and infrastructure degradation introduce intermittent, degraded, and denied network conditions as the norm rather than the exception. Maj. Gen. Mark Simerly, then the Commanding General of the Combined Arms Support Command and Sustainment Center of Excellence, emphasized the centrality of data to sustainment in this environment during a panel at the 2023 Potomac Officers Club's Army Summit, stating, *"On this battlefield, the most decisive commodity for improved sustainment is data… every line of communication is contested, extended and congested… all sustainment operations will be distributed, dispersed and disrupted."* [1] This assessment underscores a fundamental concept for modern warfare: sustainment effectiveness now hinges on the survivability and intelligent management of information flows.

1.1. Background

Legacy Command and Control (C2) systems are largely platform-centric and fragmented, characterized by siloed data systems, batch synchronization, and manual reconciliation across echelons. The Army has acknowledged that current C2 systems "lack integration, and create data silos" that limit operational visibility [2]. While these systems were not designed for fully distributed digital sustainment, they did not assume continuous high-bandwidth connectivity. In contrast, emerging Next Generation C2 (NGC2) concepts increasingly rely on integrated data fabrics and a digital backbone to enable predictive logistics and near-real-time decision-making across echelons [7].Although these architectures represent significant progress toward data integration, they introduce implicit assumptions regarding persistent connectivity and network availability, which may not hold in contested environments [9].

In contested logistics environments, neither fragmented legacy systems nor connectivity-dependent centralized models are sufficient. As data volumes increase and decision timelines compress under LogPACE objectives, logistics networks face growing risks of bandwidth saturation, latency-induced decision delays, and vulnerability to disruption. To quote LTG Michelle Donohue, "Looking ahead, it is imperative that we anticipate the demands of future sustainment requirements from the tactical edge all the way to the strategic support area to effectively execute LSCO" [3]. As that forward viewpoint is established, is must be recognized that a sustainment architecture that depends exclusively on continuous cloud reach-back or centralized processing cannot guarantee decision continuity when networks are degraded.

This paper argues that contested logistics requires distributed, mission-aware intelligence at the tactical edge (i.e. on the ground system platforms). Low-power onboard compute resident on vehicles and logistics platforms enables real-time inference, local data conditioning, and adaptive transmission strategies that respond dynamically to mission context and network state. By selectively elevating critical information at the right time, instead of indiscriminately streaming telemetry data, edge-intelligent architectures can preserve decision relevance, reduce network load, and maintain sustainment effectiveness under degraded conditions. The following sections define the contested logistics problem space, examine the architectural implications of LogPACE and evolving C2 concepts, and propose a distributed intelligence framework for resilient logistics operations in degraded networks.

2. CONTESTED LOGISTICS

Contested Logistics (CL) environments impose structural stress on sustainment architectures that were not originally designed for persistent or on-going disruption. As logistics operations become increasingly data-dependent, the underlying C2 and network architectures must reconcile two competing realities: the need for accelerated decision velocity and the inevitability of degraded communications. Understanding this tension requires examination of both legacy C2 models and emerging Next Generation Command and Control (NGC2) concepts within the context of contested operations.

2.1. Legacy C2 Architectures

Legacy logistics and sustainment systems evolved in an era characterized by platform-centric design and federated data environments. Systems were often developed to serve specific platforms, units, or functions, resulting in fragmented information flows and limited interoperability. Data exchange frequently relied on batch synchronization, manual reconciliation, or periodic updates across echelons.

The Army has formally acknowledged these limitations. An official Army publication noted that current C2 systems are "cumbersome, lack integration, and create data silos that hinder commanders' ability to visualize the battlefield holistically" [2]. This characterization reflects systemic challenges in achieving unified sustainment awareness across formations.

Similarly, modernization reporting indicates that the Army intends to retire numerous legacy systems as part of its transition toward a more data-centric C2 ecosystem, underscoring recognition that existing architectures are insufficient to support future operational requirements [3]. These legacy systems were not designed for integrated, real-time data exchange across distributed echelons.

Operationally, sustainment formations have also experienced interoperability limitations between legacy logistics systems and newer tactical network components. For example, the Army's C2 Fix initiative highlighted instances where logistics vehicles were not fully upgraded to compatible software baselines, limiting data exchanges between sustainment units and supported formations [4]. Such cases illustrate how fragmented system baselines constrain cross-echelon visibility and decision support resulting in degraded data sharing even among upgraded units.

Under contested conditions, these architectures struggle to provide timely situational awareness or enable rapid sustainment decisions. However, because they did not depend on constant high-bandwidth connectivity, their failure modes were more often procedural rather than network-induced.

2.2. NGC2 Assumptions/Risks

NGC2 initiatives seek to overcome legacy fragmentation by creating integrated, data-centric operational environments. Official Army publications describe NGC2 as a ”digital backbone” intended to unify data flows across warfighting functions, enabling predictive logistics and near-real-time sustainment decision-making. In particular, NGC2 is framed as supporting a transition from lagging sustainment reports to integrated, analytics-driven decision support at the tactical edge [7].

This vision directly aligns with LogPACE objectives of accelerating logistics decision velocity through digital integration [8]. By unifying sustainment, operational, and intelligence data streams, NGC2 aims to provide commanders with synchronized, cross-echelon visibility and improved decision dominance.

However, the architectural model described in NGC2 literature carries implicit operational assumptions. The envisioned digital backbone presumes:

- Persistent or rapidly self-healing mesh connectivity,
- Sufficient bandwidth to transport high-volume telemetry and sustainment data,
- Reliable access to enterprise or cloud-adjacent analytics resources,
- Network latency low enough to support near-real-time synchronization

While resiliency is an acknowledged design objective, the effectiveness of such an integrated data fabric depends on the sustained ability to move data across distributed formations. As senior Army leaders have emphasized, modernization efforts focus on how the force can move data across the network to enable decision advantage [5]. The ability to move data, therefore, becomes foundational.

Figure 1 provides a notional architecture for the NGC2 ecosystem. Different elements are communicating over different mediums and aggregating data back to the enterprise networks. Local mesh networks, long distance communications, multiple backhaul links, and seemingly high bandwidth connectivity.

In contested logistics environments, however, these assumptions may not survive first contact. Electronic Warfare (EW), spectrum congestion, cyber disruption, physical infrastructure degradation, and terrain constraints introduce intermittent connectivity and bandwidth variability as routine operating conditions. Under such conditions, architectures optimized for continuous synchronization risk degradation in precisely the environments where decision velocity is most critical.

Furthermore, as vehicle fleets incorporate expanding sensor suites, predictive maintenance systems, and digital mission subsystems, telemetry volume increases substantially. Continuous or high-frequency streaming models could saturate tactical networks if not intelligently conditioned. In degraded conditions, unprioritized data flows compete with fires, maneuver, and protection traffic, reducing the probability that mission-critical sustainment information is delivered in time to influence decisions.

The issue is not that NGC2 is misaligned with operational needs. Rather, its data outputs increase reliance on network availability. As data centricity expands, the fragility of connectivity becomes an operational risk multiplier. This architectural tension reinforces the need for layered mechanisms capable of sustaining decision continuity when centralized synchronization

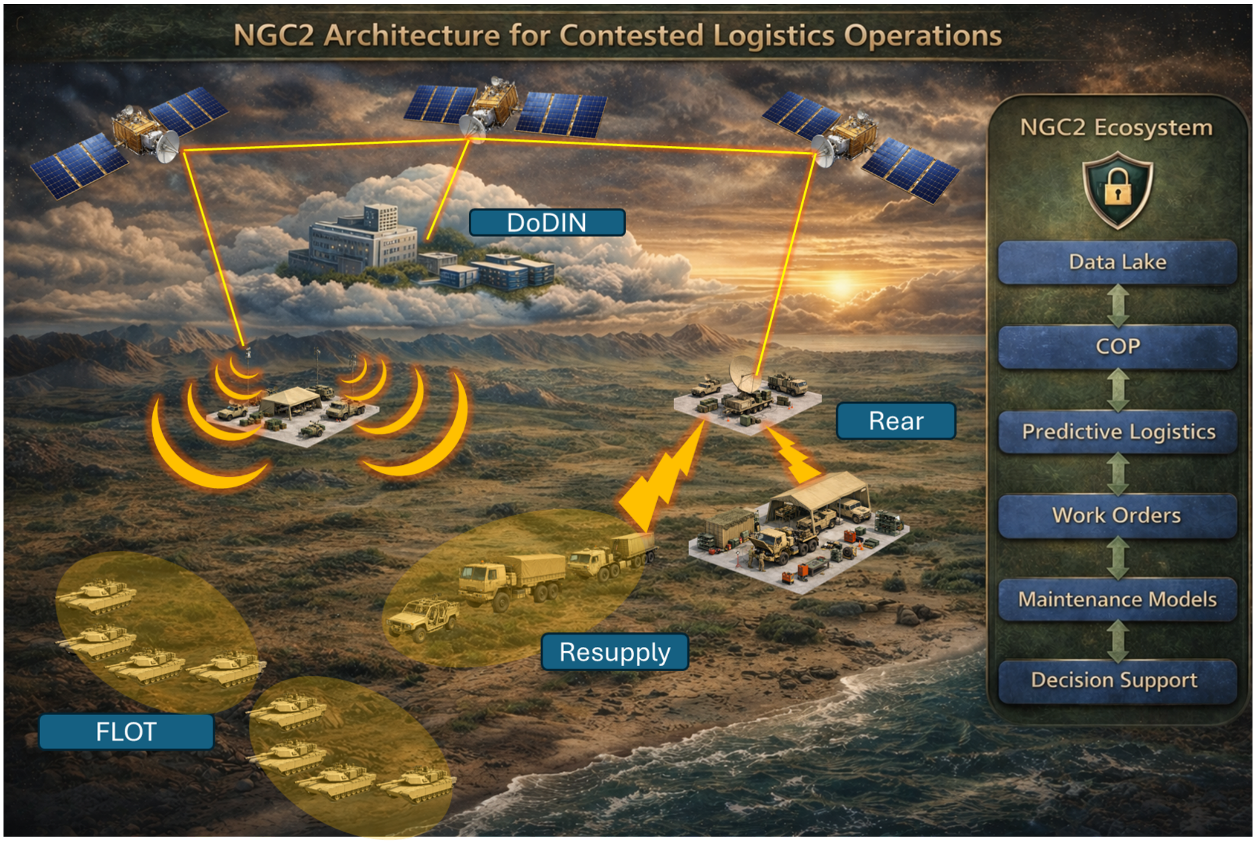

Figure 1: NGC2 Conceptual Architecture OV-1

is disrupted.

LogPACE, which seeks to accelerate logistics decision-making and distribute sustainment insight across echelons, therefore cannot rely solely on persistent mesh connectivity [6]. To achieve its objectives in contested environments, decision-relevant data must be conditioned, prioritized, and selectively elevated before transmission. Thus, distributed intelligence at the tactical edge is foundational, ensuring that integrated data architectures remain effective even when connectivity is intermittent or degraded.

2.3. Architectural Tension in CL

The resulting problem space is characterized by a structural tension:

1. Legacy architectures lack cohesive integration and speed.
2. NGC2 architectures may assume connectivity conditions that cannot be guaranteed.

As LogPACE initiatives increase demand for timely, actionable sustainment information, logistics networks must support both integration and resilience. Contested logistics therefore requires an architectural approach that preserves decision continuity in degraded conditions while avoiding overreliance on persistent network availability.

The following sections propose distributed, mission-aware intelligence at the tactical edge as a complement to centralized architectures. By shifting certain decision functions and data conditioning capabilities onboard vehicles and logistics nodes, sustainment systems can adapt dynamically to network state, reduce bandwidth strain, and maintain operational effectiveness in degraded environments.

3. DECISION VELOCITY

Logistics operations in LSCO are increasingly characterized by dispersion, contested lines of communication, and compressed decision timelines. Traditional sustainment processes, built around periodic reporting and centralized synchronization, are insufficient to support distributed formations operating under persistent disruption. LogPACE represents an institutional response to this reality, emphasizing accelerated logistics decision-making through digital integration, a multitude of communication methods, improved data visibility, and synchronized sustainment operations.

3.1. LogPACE Objectives

LogPACE initiatives seek to increase the tempo and precision of sustainment decision-making across echelons. Central to this objective is the transition from retrospective reporting toward near-real-time awareness of fleet health, supply status, and distribution posture through multiple communications methods when available. By leveraging digital integration, common data standards, and analytics-enabled insight, LogPACE aims to:

- Reduce latency between data generation and sustainment decision
- Increase cross-echelon visibility of logistics status
- Enable predictive rather than reactive sustainment actions
- Support distributed sustainment operations in contested environments

These objectives reflect a broader shift toward decision dominance in sustainment. As senior Army leadership has emphasized, data has become a decisive enabler of logistics effectiveness in contested battlespaces [1]. LogPACE therefore increases both the value of timely data and the dependency on reliable information exchange.

However, accelerating decision velocity through integration also increases sensitivity to network performance. As the volume and frequency of sustainment data exchange expands, the architecture supporting that exchange becomes a potential liability. If logistics decision cycles depend on centralized analytics and continuous synchronization, degraded connectivity can directly translate into reduced decision velocity.

3.2. Architectural Implications

LogPACE's emphasis on decision speed introduces structural requirements for sustainment architectures operating in contested environments. Specifically, achieving accelerated logistics decision-making requires:

- Continuous or near-continuous data availability,
- High-confidence data provenance and integrity,
- Timely cross-echelon dissemination,
- Minimal latency between detection and action.

In persistent connectivity environments, centralized analytics and enterprise-level data aggregation can satisfy these requirements. In degraded or denied networks, however, reliance on centralized processing introduces vulnerability. When data must traverse contested links before it becomes actionable, the decision loop elongates.

Further, the reliance on a centralized network assumes similar bandwidth links between the tactical edge and the enterprise. In LSCO, the different connection layers may be orders of magnitude different in bandwidth. A localized mesh network may enable lower echelon cohesion, but be bottlenecked at a single lower bandwidth uplink from a centralized location. Which information transits that link and why must be balanced with logistics data likely to take a lower priority than fires, orders, or Situation Reports (SITREPs).

The architectural implication is clear: if decision velocity is to be preserved under degraded conditions, certain decision functions must migrate closer to the point of data generation. Rather than treating vehicles and tactical platforms solely as data producers feeding higher-echelon analytics with their telemetry, they must be capable of performing local inference and conditioning of data before transmission.

In this context, distributed intelligence is a key enabler for integrated C2 or NGC2 constructs. It is a complement that ensures decision continuity when network assumptions breakdown. By enabling onboard compute to perform real-time analysis, detect relevant events, and prioritize information based on mission context and connectivity state, sustainment architectures can maintain operational tempo even when centralized synchronization is disrupted.

LogPACE's objectives therefore reinforce the necessity of adaptive, edge-resident intelligence. As logistics operations become more digitally integrated and decision timelines compress, architectures must be designed not only for integration but also for survivability. The next section defines the technical requirements for distributed intelligence in degraded networks and outlines the functional characteristics necessary to enable contested logistics at the tactical edge.

4. DISTRIBUTED INTELLIGENCE IN DEGRADED NETWORKS

If the Army's response to a CL environment is to achieve LogPACE objectives under degraded conditions, sustainment architectures must incorporate distributed intelligence as a foundational capability rather than a future milestone. As the Army's Unified Network Plan 2.0 emphasizes, modern operations require secure, interoperable computing and data services available across distributed formations to enable data-driven decision-making at echelon [10]. In contested environments, this requirement extends beyond systems integration to survivability.

4.1. Edge Compute Requirements

Distributed intelligence begins with the presence of onboard compute resources capable of operating across a heterogeneous fleet. These resources must be low-power, vehicle-agnostic, and scalable from low-cost platforms to high-end systems. The objective is not to replicate enterprise analytics at the edge, but to enable real-time conditioning and prioritization of sustainment-relevant information with at-platform support for mainteancne while in the fight.

The Army Unified Network Plan 2.0 identifies the need for integrated information services and a Common Operating Environment (COE) capable of supporting secure applications and decision tools across distributed nodes [10]. Extending this concept to contested logistics requires that computing resources be resident where data is generated, not solely where it is aggregated.

Core edge compute requirements therefore include:

- **Real-time data ingestion**: Continuous monitoring of vehicle telemetry, health metrics, and mission system outputs.
- **Local inference capability**: Execution of lightweight models for anomaly

detection, health-state classification, and event identification.
- **Mission-context awareness**: Ability to weight data relevance based on operational phase, mission priority, or commander's intent.
- **Connectivity-state awareness**: Detection of network quality, latency, bandwidth availability, and link status.
- **Store-and-forward resilience**: Local data persistence during isolation events with controlled synchronization upon reconnection.
- **Policy-driven behavior**: Configurable decision logic governing what information is elevated, suppressed, compressed, or deferred.

Edge compute must function independently during network isolation while remaining interoperable with higher-echelon systems when connectivity is restored. This ensures continuity of sustainment awareness at the platform level without introducing architectural fragmentation.

4.2. Adaptive Communications

Distributed intelligence must be coupled with adaptive communications mechanisms that respond dynamically to contested network conditions. The DoD Command, Control, and Communications (C3) Modernization Strategy acknowledges that the tactical communications landscape remains complex and fragmented and emphasizes the need for survivable and resilient communications architectures capable of operating in contested environments [9]. This modernization imperative reflects the operational reality that connectivity cannot be assumed.

In degraded environments, inflexible transmission policies are insufficient; the architecture must condition information flow according to both mission relevance and available transport pathways.

Key adaptive communication requirements include:

- **Priority-based transmission logic**: Classification of data into tiers (mission-critical, operationally relevant, deferred) with differentiated transmission behavior.
- **Bandwidth-aware compression and summarization**: Reduction of raw telemetry into abstracted health states, deltas, or event-driven messages when bandwidth is constrained.
- **Opportunistic synchronization**: Burst transmission of queued data during brief windows of connectivity.
- **Multi-path transport flexibility**: Utilization of Radio Frequency (RF) and non-RF communication methods, including line-of-sight, relay, optical, wired, or physical transfer mechanisms where appropriate.
- **Transmission suppression under saturation**: Automatic throttling of non-critical data to preserve network capacity for higher-priority traffic.

Adaptive communications must be tightly integrated with edge intelligence logic. Connectivity state must influence not only transmission timing but also the level of abstraction applied to outgoing data. For example, in high-bandwidth conditions, detailed telemetry may be synchronized. Under degraded conditions, only summarized health states or event-triggered alerts may be transmitted. Each communication medium supported may support one or more bandwidth conditions.

4.3. Selective Data Elevation Model

The integration of edge compute and adaptive communications enables a selective data elevation model. Rather than assuming continuous streaming of full-fidelity vehicle telemetry, data is evaluated at the point of origin and elevated according to mission value and network conditions. A selective data elevation model includes:

- **Event-driven reporting**: Transmission triggered by threshold breaches, anomalies, or mission-relevant changes.
- **Delta-based synchronization**: Transmission of incremental changes rather than complete state replication.
- **Hierarchical abstraction**: Representation of detailed telemetry as higher-order health indicators when bandwidth is limited.
- **Connectivity classification states**: Operational modes (e.g., nominal, constrained, denied) that dynamically adjust reporting behavior.

This model preserves the benefits of integrated data-centric operations described in modernization strategies while reducing dependence on continuous network availability. It also mitigates bandwidth saturation risks inherent in high-volume telemetry streaming models. The average tactical vehicle (based on total vehicle population) has two vehicle data buses, each running at about 250 kilobits per second (kbps). A brigade will operate approximately 800 such vehicles, with an aggregate bandwidth of 400 Megabits per second (Mbps). Even with the knowledge that vehicle telemetry buses tend to operate at below 80%, a constant stream of full rate data from the brigade would be overwhelming for the network infrastructure that also has to support the rest of the force.

4.4. Synergy with NGC2 and LogPACE

Distributed intelligence at the tactical edge does not replace centralized analytics or NGC2 data fabrics. Instead, it serves as a structural complement that increases resilience. When connectivity is nominal, edge nodes participate in synchronized data exchange and contribute to enterprise-level analytics. When connectivity is degraded, edge nodes preserve decision continuity locally and elevate only mission-critical information.

By conditioning data before transmission and adapting to network state, distributed intelligence aligns with the Army's broader modernization objectives for secure, interoperable, and survivable networks [9], [10]. The architecture thereby shifts from a connectivity-dependent model to a connectivity-adaptive model, enabling LogPACE decision velocity even under contested conditions.

5. OPERATIONAL IMPACT UNDER CONTESTED CONDITIONS

The architectural shift from connectivity-dependent logistics to connectivity-adaptive logistics produces measurable operational effects. Distributed intelligence at the tactical edge directly influences bandwidth utilization, decision continuity, survivability, and sustainment tempo in contested environments. As Army sustainment leadership has articulated, contested logistics environments are characterized by adversary actions that directly challenge sustainment networks and data flows, requiring resilient and predictive logistics architectures [11]. Distributed intelligence must therefore be evaluated not only as a technical construct but for operational impact.

5.1. Bandwidth Efficiency and Survivability

In traditional centralized models, sustainment telemetry is often transported in high frequency or full-fidelity form to higher-echelon analytics environments. As vehicle platforms incorporate expanded sensor suites, Condition-Based Maintenance (CBM) systems, and digital mission subsystems, raw data volume grows accordingly. Under contested spectrum conditions, indiscriminate telemetry streaming increases the likelihood of network congestion and information loss.

The contested logistics environment, as described by Army sustainment leaders, involves adversary efforts to disrupt and degrade lines of communication and digital sustainment systems [11]. Simultaneously, the DoD Information Network (DoDIN) is both foundational to joint operations and a target in contested environments, reinforcing the necessity of survivable communications architectures [12].

A selective data elevation model reduces network burden by abstracting, compressing, or suppressing non-critical telemetry before transmission. Instead of competing equally with fires, maneuver, and intelligence traffic, sustainment data is tiered according to mission relevance and network state. This prioritization:

1. Reduces aggregate bandwidth consumption,
2. Preserves capacity for mission-critical communications,
3. Increases probability of delivery for high-value data,
4. Mitigates congestion-induced latency

In electromagnetic-contested environments, where bandwidth availability fluctuates and transport pathways may be intermittent, reducing unnecessary transmission directly enhances survivability of the broader communications architecture.

5.2. Decision Continuity During Network Degradation

Contested logistics operations frequently involve temporary isolation of tactical elements due to terrain, enemy action, or infrastructure disruption. In centralized analytics models, loss of backhaul connectivity can stall decision cycles, as data must traverse higher-echelon systems before insight is generated.

Army sustainment doctrine increasingly emphasizes predictive, integrated logistics capabilities to maintain operational tempo under disruption [10]. Edge-resident inference mitigates vulnerability by enabling local decision support. Vehicles and sustainment nodes equipped with onboard compute can:

- Detect anomalies or health degradations in real time
- Generate summarized health states
- Trigger mission-relevant alerts locally
- Queue prioritized updates for opportunistic transmission

This capability preserves decision continuity even when network synchronization is unavailable. Rather than halting sustainment insight until connectivity is restored, tactical nodes maintain a degraded-but-functional decision loop. Most importantly, this does not eliminate enterprise analytics; it ensures that the absence of centralized synchronization does not equate to absence of insight.

5.3. Sustainment Tempo and LogPACE Alignment

LogPACE seeks to accelerate logistics decision velocity by reducing latency between observation and action. In persistent-connectivity environments, centralized analytics may achieve this objective. In degraded environments, however, the decision loop elongates if data must be transported before interpretation.

Modern contested logistics principles emphasize that "logistics wins wars when data leads the fight," underscoring the necessity of timely, protected, and prioritized information flows [11]. Distributed intelligence shortens the sustainment decision loop by relocating certain analytic functions to the point of data generation. This architectural adjustment:

- Reduces time between anomaly detection and awareness,
- Enables faster maintenance triage decisions,
- Supports predictive sustainment actions at lower echelons,
- Maintains operational tempo despite connectivity constraints

By conditioning data locally and elevating only mission-relevant information, distributed intelligence ensures that LogPACE objectives remain achievable under contested conditions.

5.4. Scalability and Risk Reduction

A key operational advantage of low-power, vehicle-agnostic onboard compute is scalability across heterogeneous fleets. CL environments rarely involve homogeneous platforms; formations often include legacy vehicles, modernized systems, unmanned assets, and commercial support elements.

An edge-intelligent architecture that is modular, lightweight in power consumption, and interoperable with existing C2 ecosystems can scale incrementally across formations without requiring wholesale redesign. Distributed intelligence also reduces systemic fragility. When insights are generated across many nodes rather than concentrated in centralized systems, loss of individual connectivity pathways does not collapse the sustainment architecture.

In environments where adversaries actively contest communications and digital infrastructure, architectures that assume continuous synchronization introduce risk. Connectivity-adaptive sustainment architectures mitigate this risk by:

- Minimizing reliance on constant backhaul,
- Conditioning information before transmission,
- Preserving local insight during isolation,
- Ensuring mission-critical data has transmission priority

The result is not elimination of network risk, but reduction of its operational consequences. Distributed intelligence transforms logistics systems from connectivity-dependent to connectivity-resilient, aligning sustainment operations with the realities of contested warfare. For example, if a tank company loses connectivity to the LogPACE architecture and must still complete their assigned mission, the commander can still make a well-informed decision when assigning a platoon support-by-fire versus an attack-by-fire mission. By leveraging real-time health and logistics status data visible at the edge (i.e., at the platoon or vehicle level), the commander can quickly select the most capable platoon for the task. Table 1 shows the comparison between a centralized model where all the information must make it back for decision making, and an Edge-Intelligent Model where the vehicle platforms have their own processing.

6. IMPLICATIONS FOR FUTURE LOGISTICS ARCHITECTURES

The preceding sections established that contested logistics environments impose structural stress on both legacy and emerging C2 architectures, and that LogPACE

Table 1: Centralized vs Edge-Intelligent Architectures

Metric	Centralized Model	Edge-Intelligent Model
Bandwidth Use	High (continuous streaming)	Adaptive (prioritized / selective)
Latency	Network-dependent	Local-first, reduced latency
Survivability	Low under degraded networks	High with graceful degradation
EW Resilience	Limited	Enhanced through adaptive comms
Decision Continuity	Fragile during disconnects	Sustained via local inference

objectives increase dependence on timely, decision-relevant data exchange. This section examines the broader architectural implications of adopting distributed intelligence at the tactical edge and its role in shaping future sustainment systems.

6.1. Connectivity-Adaptive Systems

Traditional digital logistics architectures can be characterized as connectivity-dependent: data is generated at tactical nodes, transported to higher echelons, processed centrally, and then redistributed as decision guidance. Under persistent connectivity, this model can deliver high-fidelity situational awareness and enterprise-level optimization.

In degraded environments, however, centralized synchronization introduces latency and fragility. Distributed intelligence reframes the architecture as connectivity-adaptive. In this model:

- Tactical nodes generate and interpret data locally.
- Transmission behavior adapts dynamically to network state.
- Higher-echelon systems receive conditioned, prioritized information rather than unfiltered telemetry.

This shift strengthens integrated C2 constructs such as NGC2 by ensuring that data fabrics remain effective even when network conditions fluctuate. The result is an architecture capable of surviving degradation rather than abrupt decision collapse.

6.2. Implications for Implementation

LogPACE seeks to accelerate logistics decision velocity across echelons. Achieving this objective requires more than integration; it requires survivable integration. As decision timelines compress, reliance on uninterrupted data synchronization becomes increasingly risky in contested environments. Distributed intelligence supports LogPACE by:

- Preserving decision continuity during network isolation,
- Reducing transport latency through local inference,
- Elevating only mission-relevant data to higher echelons,
- Enabling lower-echelon sustainment autonomy consistent with commander's intent

In effect, LogPACE and distributed intelligence are mutually reinforcing. LogPACE defines the decision-speed objective; edge intelligence provides a resilient mechanism to achieve it under degraded conditions.

6.3. MOSA Alignment

Future logistics architectures must operate across heterogeneous fleets and evolving technology baselines. Modular Open Systems Approach (MOSA) principles emphasize interoperability, modularity, and vendor-agnostic integration. Distributed intelligence architectures that are: 1) Platform-agnostic, 2) Based on open interfaces, 3) Decoupled from proprietary data silos, and 4) Lightweight in power and compute requirements are inherently aligned with MOSA objectives. By abstracting sustainment insight at the edge, such systems reduce integration friction and support incremental modernization across fleet classes.

Additionally, selective data elevation reduces the risk that proprietary telemetry formats or platform-specific data schemas become bottlenecks for integration. Abstracted health states and standardized event messages improve cross-platform compatibility.

6.4. Risk and Operational Resilience

Contested logistics environments are defined by uncertainty. EW, cyber disruption, and physical interdiction introduce variability in both data generation and data transport. Architectures optimized exclusively for peak network performance may underperform when stressed. Distributed intelligence introduces resilience through decentralization. When analytic capability is distributed across multiple nodes:

- The loss of individual links does not eliminate decision support.
- Network saturation does not automatically equate to sustainment blindness.
- Tactical formations retain bounded decision autonomy.

This decentralization mirrors broader military principles of mission command: empowering lower echelons with the information necessary to act within commander's intent. In this context, distributed intelligence becomes a digital analogue to doctrinal decentralization.

6.5. Future Development

Implementing distributed intelligence within contested logistics architectures requires careful consideration of:

- Model validation and lifecycle management for onboard inference engines
- Cybersecurity controls for edge-resident decision logic
- Data provenance and synchronization reconciliation upon reconnection
- Policy frameworks governing transmission prioritization

Future experimentation and field validation should focus on quantifying:

- Bandwidth reduction achieved through selective data elevation
- Latency reduction in anomaly-to-awareness timelines
- Sustainment tempo improvements during network degradation scenarios

Such empirical evaluation will further refine the architectural balance between centralized analytics and distributed edge intelligence.

7. CONCLUSIONS

Contested logistics environments expose structural limitations in sustainment architectures that assume persistent connectivity and centralized analytics. Legacy C2 systems remain fragmented and siloed, limiting integration and decision velocity. Emerging NGC2 concepts promise unified data fabrics and accelerated decision-making but implicitly rely on resilient, near-continuous network connectivity. In degraded or denied electromagnetic environments, these assumptions may not hold. As sustainment operations become increasingly data-dependent, connectivity fragility becomes an operational risk multiplier.

LogPACE initiatives seek to accelerate logistics decision velocity through digital integration and data-centric operations.

However, integration alone is insufficient if the supporting architecture cannot adapt to contested conditions. To preserve decision continuity and sustainment effectiveness, certain analytic and prioritization functions must migrate closer to the point of data generation.

This paper argued that distributed, mission-aware intelligence at the tactical edge provides a structural complement to centralized C2 architectures. Low-power, vehicle-agnostic onboard compute enables real-time inference, local data conditioning, and connectivity-aware transmission strategies. By selectively elevating mission-relevant information based on network state and operational context, edge-intelligent architectures reduce bandwidth strain, improve survivability of communications networks, and preserve sustainment insight during periods of isolation.

The resulting architecture is connectivity-adaptive rather than connectivity-dependent. When network conditions are favorable, distributed nodes participate in synchronized enterprise analytics. When networks are degraded, tactical elements retain bounded decision capability and elevate only prioritized information. This approach aligns with Army modernization objectives for resilient networks, supports MOSA interoperability principles, and reinforces LogPACE goals for accelerated sustainment decision-making.

Future work should focus on empirical validation of selective data elevation models, quantification of bandwidth reduction and latency improvements, and operational experimentation under degraded network conditions. As contested environments become the baseline rather than the exception, sustainment architectures must be designed not only for integration and speed, but for survivability and adaptability.

Distributed intelligence at the tactical edge offers a practical, scalable pathway to enable logistics in degraded networks while preserving the decision advantage required for modern ground operations.

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9. ACRONYMS

C2 Command and Control
C3 Command, Control, and Communications
CBM Condition-Based Maintenance
COE Common Operating Environment
CL Contested Logistics
DOD Department of Defense
DoDIN DoD Information Network
EW Electronic Warfare
kbps kilobits per second
LSCO Large-Scale Combat Operations
Mbps Megabits per second
MOSA Modular Open Systems Approach
NGC2 Next Generation Command and Control
RF Radio Frequency
SITREPs Situation Reports