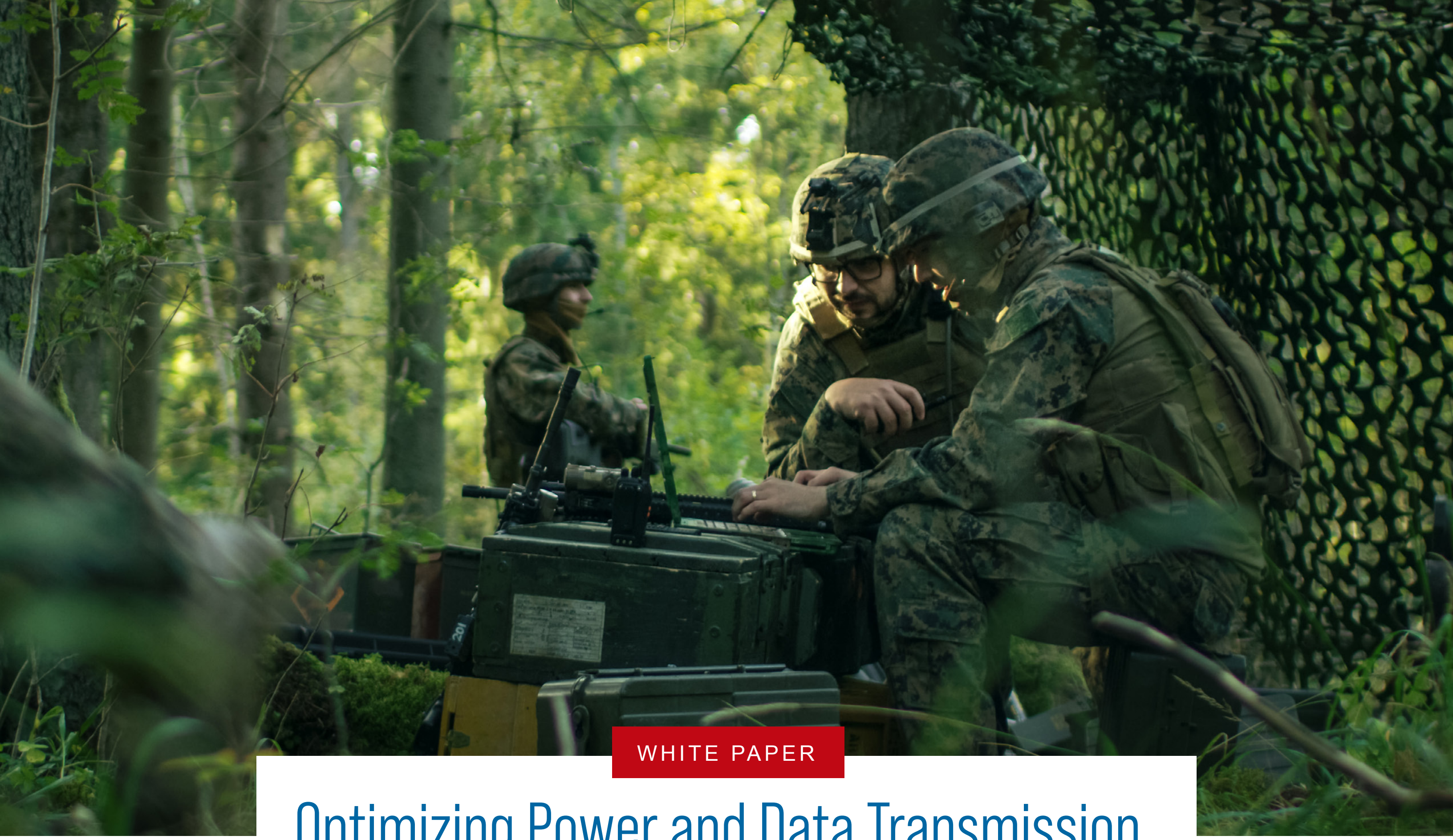

WHITE PAPER

# Optimizing Power and Data Transmission in Compact Defense Platforms


## Abstract

From UAVs and portable communications kits to mobile command nodes and autonomous ground vehicles, the need for reliable power delivery and high-speed data transmission is high. With space at a premium as compact defense systems add more sensors, onboard compute, autonomy, and encrypted communications, engineers must find ways to move power and data through smaller, harsher enclosures. The most resilient architectures treat copper, fiber, RF, and connector technology as complementary tools to solve tight size, weight, and power (SWaP) constraints.

Shielded cable assemblies support internal networking and control, low-loss coaxial assemblies feed rugged antennas for RF links, and rugged fiber optic assemblies provide high-bandwidth transport that is immune to Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) along the optical path. When these elements are selected, routed, and qualified as a single system, it reduces late-stage redesign, improves mission-critical communications, and leads to platforms with better endurance, reliability, and maintainability.

# The Shift Toward Compact Defense Systems

More compact defense platforms aren't just about miniaturization. They're about increasing performance density within constrained SWaP environments. Modern military drones (and other deployable defense platforms) must simultaneously support intelligence, surveillance and reconnaissance (ISR) video, telemetry, global navigation satellite system (GNSS), flight-control traffic, sensor fusion, AI/edge processing, payload integration, and secure backhaul links. Portable communications systems and edge-computing-enabled defense platforms need to deliver reliable power and high-speed data in compact, harsh environments. As these functions and their corresponding components increase density, every routing decision grows in importance as each will affect weight, endurance, heat, maintainability, and electromagnetic compatibility. In short, SWaP optimization in defense electronics is no longer a packaging exercise, it's an architectural discipline.

A single UAV architecture carries many connectivity types at once, so designers depend on rugged Ethernet cables and shielded copper harnesses for internal data paths, coaxial assemblies and antennas for wireless and radar links, and fiber optic communication for EMI-immune backbone transport. The goal is not simply to fit everything inside the enclosure. It is to preserve performance when the enclosure is hot, vibrating, wet, dusty, or electrically noisy.

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# Core Challenges in Compact Platforms

## Space Constraints

Compact airframes leave limited room for bends, shielding, connector backshells, and service loops. Integration becomes especially difficult when Ethernet/copper, coaxial RF, and power conductors must share the same pathway. Connector stacking and mixed connector families consume unexpected volume and complicate service access. Poorly planned routing increases insertion loss, constrains maintenance access, and forces late mechanical changes.

## Power Density and Efficiency

Power budgets are tightening even as payloads become more demanding. Electro-optical sensors, radios, processors, and storage all compete for limited power in small footprints. Under mission conditions, every watt lost to inefficiency reduces range or payload margin. Resistance losses, unnecessary cable length, and poorly balanced distribution all convert energy into potentially detrimental heat. Efficient routing, proper conductor sizing, and compact high-reliability cable assemblies help preserve endurance and reduce thermal load.

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## Signal Integrity and Data Throughput

Modern platforms depend on high-speed data transmission for ISR video, LiDAR (Light Detection and Ranging), radar, electronic warfare sensing, and onboard analytics. Copper remains valuable for flexible networking and legacy interfaces, but dense electrical environments increase susceptibility to EMI/RFI. Fiber addresses this by delivering high-bandwidth optical networks with complete immunity to

EMI, while low-loss coaxial cables preserve RF signal integrity between radios, filters, and antennas. In mixed systems, impedance matching, return loss, and connector retention become critical design variables rather than afterthoughts. This is especially true when 50-ohm RF, 75-ohm video, and 78-ohm twinax interfaces coexist in one vehicle.

### Environmental and Operational Stress

Military drones operate under sustained vibration, shock and environmental exposure that directly impact interconnect performance. Vibration from motors or tracked mobility, shock during launch or transport, temperature swings, moisture, dust, salt, and corrosion all attack interconnect reliability. Bench success is not enough — optimum field performance is the bare minimum. So, high-reliability cable assemblies need rugged jackets, sealed interfaces, strain relief, and vibration-resistant connectors. IP-rated assemblies, especially IP66/IP67 fiber and IP67/IP68 sealed cable systems, are often necessary in conditions exposed to moisture, dust, temperature extremes and other environmental stressors.

## 4 Design Considerations for Optimized Transmission

Cables, connectors, antennas, and how they all interact with power are critical design considerations for engineers to address in modern UAVs.

### 1. Cable Selection

The mission and the environment are the two most important concerns when it comes to selecting the proper cables. When flexibility and easy termination matter, shielded Ethernet and other military-grade cable assemblies are well suited for internal avionics networking, control, and payload interconnection. Fiber optic assemblies are often better where bandwidth is high, cable weight matters, or EMI-heavy environments make copper risky. Coaxial cable assemblies remain essential for low-loss RF transmission, antenna feeds, telemetry, satellite communications (SATCOM), and radar. For each option, shielding effectiveness (whether braided, foil, or hybrid) must be weighed against bend radius, crush resistance, flex life, durability, and mass.

### 2. Connector Technology

Choosing the right connectors can make a huge difference in your design. Systems must achieve miniaturization without sacrificing retention, sealing, or electrical performance. Rugged coaxial connectors with threaded or locking interfaces help maintain stable impedance in high-vibration conditions, while compact circular or M12-style connectors can simplify dense panel layouts. Where feed-through mounting is required, TRB (threaded RF bayonet) bulkhead adapters such as LCCN310-06580 support secure panel transitions for twinax interfaces, including MIL-STD-1553-style signal paths where appropriate. Excessive adapter chains should be avoided because every interface adds loss and mechanical risk.

### 3. Power Distribution Strategies

Power distribution strategies minimize unnecessary length, separate noisy and sensitive circuits, and balance loads. This will ensure hot spots don't form in one harness branch or enclosure wall. Quality terminations reduce resistive loss, while better routing simplifies inspection, troubleshooting, and replacement. System-level power management is most effective when cable assemblies, connectors, and thermal strategy are defined as one, rather than in separate design phases.

### 4. Data Transmission Architecture

While copper-versus-fiber-versus-RF appears to be the decision, it's more complex than that. Fiber is ideal for high-bandwidth, EMI-immune transport such as video backbones or sensor aggregation. Copper remains practical for internal networking, control traffic, and legacy avionics interfaces because it is flexible, field-serviceable, and easy to integrate. Coaxial assemblies paired with antennas enable wireless command, telemetry, GNSS, radar, and other RF functions that no wired medium can replace. To get the most from these options, designers must choose the medium that's best for each link type before coordinating bandwidth, latency, shielding, and maintainability at the system level.

## Addressing Additional Variables in Compact Defense Systems

### Avoiding Interference in Dense Systems

EMI/RFI mitigation must be addressed early in dense defense platforms to prevent signal degradation, interference and costly redesigns later in the development cycle. Cable selection plays a critical role, with different constructions offering varying levels of shielding effectiveness, noise isolation and signal integrity.

While shielded military cable assemblies protect internal Ethernet and control links, shielding is only as good as its continuity across backshells, connector transitions, and grounding points. Coaxial cable assemblies can create controlled RF paths, which reduces unintended coupling between radios and nearby circuits. Fiber optic assemblies provide the cleanest answer where electrically noisy subsystems coexist with high-speed data, especially in electronic warfare environments.

Effective EMI/RFI mitigation also requires disciplined cable separation, consistent bonding, minimized adapter stacking, and grounding strategies that avoid creating new noise problems while solving old ones.

### Managing Heat in High-Density Enclosures

Elevated temperature increases conductor resistance, stresses insulation, alters RF performance, and shortens connector life. Heat can be the silent reliability killer in compact enclosures. As a result, copper and coax require close attention to current loading, spacing, and ventilation. Fiber cabling can reduce cable mass and avoid resistive heating in the transmission medium, though associated optoelectronics still contribute to the thermal budget.

To get the best picture of potential heat issues, thermal modeling must include boards, processors, and even harness bundles. Make sure to evaluate passive cooling, conductive paths, and thoughtful harness placement before adding active cooling — every fan or pump needs power and reduces available space.

### Planning for Rugged Defense Environments

While bench validation is an important step, defense interconnects must not only survive but perform at a high level in the real world. Selecting rugged cable assemblies with strain relief, abrasion resistance, and jackets suited to chemicals, UV exposure, or extreme temperatures can help boost in-the-field performance.

Environmental factors must be evaluated for their impact on interconnect performance. For example, where moisture intrusion or dust can degrade long-term performance, it's important to use sealed coaxial connectors and cable assemblies.

The right strain-relief geometry is also a key factor. Mechanical reinforcement at clamp points, connector retention features, and environmental sealing around bulkheads can all improve system reliability.

## Solutions for Compact Defense Platforms

Compact defense platforms benefit most from integrated solution sets rather than isolated components.

- For power and data transmission inside the platform, rugged military cable assemblies provide dependable networking and control paths with shielded Cat5e/Cat6 or similar copper options.
- For RF-critical subsystems, military coaxial cable assemblies, rugged RF connectors, adapters, filters, DC blocks, and antennas support stable links between radios, payloads, GNSS receivers, and external apertures.
- For bandwidth-intensive traffic, industrial/military-grade fiber optic cable assemblies deliver lightweight, EMI-immune transport for video, sensing, and backbone communication.

Hybrid architectures combine these so the platform can move control data, payload data, and RF energy through the same constrained space without forcing one medium to do everything.

High-performance connectors and adapters complete the architecture. Precision RF connectors, sealed coaxial adapters, and bulkhead feed-throughs help maintain signal continuity across panels and subsystems, especially where antenna lines, radar modules, or MIL-STD-1553/twinax interfaces must cross enclosure boundaries.

Development practices behind the hardware, like rapid prototyping for fit checks, qualification-oriented testing, inspection, and engineer-to-engineer support, are also important.

## Application Use Cases

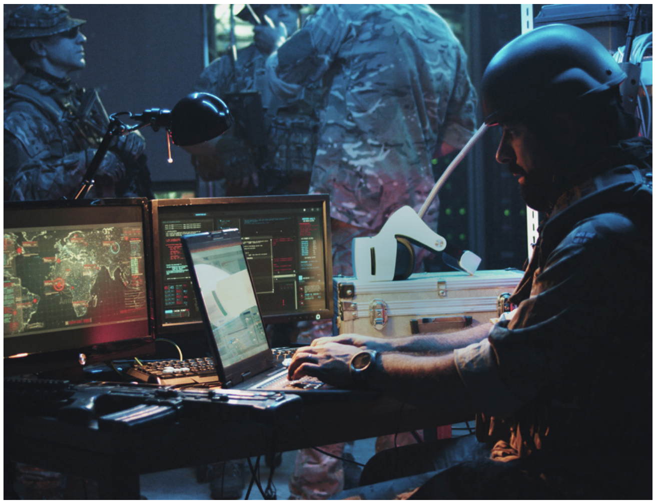
Many mission profiles require the same design principles. In every case, secure and stable data transmission depends on choosing the medium that fits the link, the environment, and the mission. Here are a few examples:

1. **UAV payload systems:** To support flight-control and avionics-bus links, UAV payload systems typically use fiber or shielded Ethernet for camera and sensor data, coaxial assemblies plus antennas for RF communications, GNSS, and telemetry, and copper/twinax.
2. **Mobile command units:** These need rugged connectivity between radios, compute nodes, displays, and external antennas while operating in dust, vibration, and temperature extremes.
3. **Tactical communications kits:** Compact, field-repairable assemblies that balance durability with portability are a must.
4. **Autonomous ground vehicles:** Shock, contamination, and higher-current distribution challenges exist due to conditions these vehicles must traverse, so cable routing and sealing is crucial.

## Best Practices Checklist

For compact defense platforms, make sure to:

- Optimize cable routing early in the mechanical design.
- Use fiber optic cable assemblies in EMI-heavy zones.
- Standardize connector families wherever possible.
- Validate insertion loss, return loss, and thermal rise.
- Choose locking, vibration-resistant, IP-rated interfaces.
- Balance weight, serviceability, and durability.
- Include qualification planning before final layout freeze.



## Looking Ahead at Compact Defense Platform Engineering

Design trade-offs are only going to become more challenging, especially as AI and edge computing drive higher internal data rates. Along with Edge AI needs, military drones and other compact defense platforms will rely on more industrial/military-grade fiber for bandwidth and EMI immunity, while RF subsystems will continue expanding through more capable antennas, low-loss coax, and tighter frequency coexistence requirements. At the same time, these demands will drive the need for smaller, lighter, and more rugged cable and connector solutions that can be qualified faster, customized more easily, and scaled more smoothly from development builds to production deployment.

## From Design Trade-Offs to Field Performance

Ultimately, optimizing power and data transmission in compact defense platforms is a system-design challenge. SWaP limits, signal integrity, RF coexistence, thermal stress, and environmental exposure are all interconnected, meaning each decision affects other elements of your design. This means cabling and connector choices made late or in isolation can become mission problems.

The most successful designs keep harsh real-world conditions at the forefront of what they must combat by combining rugged copper assemblies, EMI-immune fiber optic links, and low-loss RF interconnects in a coordinated architecture built. By selecting the right cable assemblies, coaxial connectors, antennas, bulkhead interfaces, and fiber solutions early, teams can reduce rework, improve qualification outcomes, and field more resilient aerospace and defense systems.

With a partner like L-com, you can get support for rapid prototyping, testing, compliance, and production for rugged, high-performance connectivity in aerospace and defense-ready solutions. It's not only about unparallelled quality, but decades of expertise from the industry leaders in RF and connectivity products. The company also provides assurance that you'll get reliable components on trusted timelines.