Building Sustainable Network Resiliency in SATCOM Systems

More than meets the eye

by LtCol Christopher S. Tsirlis (Ret)

The need for resilient networks is becoming increasingly crucial, especially as global SATCOM systems evolve to meet the demands of the DOD, the Marine Corps, and its mission partners. These systems must be adaptable, redundant, and capable of operating seamlessly under stress. To achieve true network resiliency, we must move beyond traditional approaches and explore strategies that allow systems not only to withstand disruptions but to thrive in challenging environments. This article reevaluates current SATCOM resiliency strategies and proposes an approach that enhances sustainability and adaptability in unpredictable operational landscapes.

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Figure 1. Airbus Ranger 1200 Multi-Frequency Terminal. *(Figure provided by author.)*

The Push for Transport Diversity

Transport diversity is foundational to modern SATCOM systems, encompassing multi-band and multi-orbit capabilities. This diversity is critical for enhancing operational resilience in contested environments, ensuring that communication pathways remain reliable even under hostile conditions. For example, during adversarial interference such as jamming or cyberattacks, transport diversity enables forces to seamlessly switch between different frequency bands or orbits, preserving connectivity and ensuring continued mission success.

Transport diversity also allows for greater operational flexibility by adapting to the dynamic demands of modern missions. It reduces the risk of single points of failure and strengthens overall adaptability. In a NATO training exercise, for example, forces using a multi-orbit SATCOM system successfully maintained communication by switching between low Earth orbit (LEO) and geostationary Earth orbit (GEO) satellites when GEO signals were jammed. This adaptability proved the effectiveness of multi-orbit systems in preserving mission-critical communications.

However, implementing multi-orbit systems presents challenges. The complexity of managing multiple bands and orbits can introduce risks, such as delays during transitions between orbits. For example, a recent military exercise has revealed that conflicting prioritization

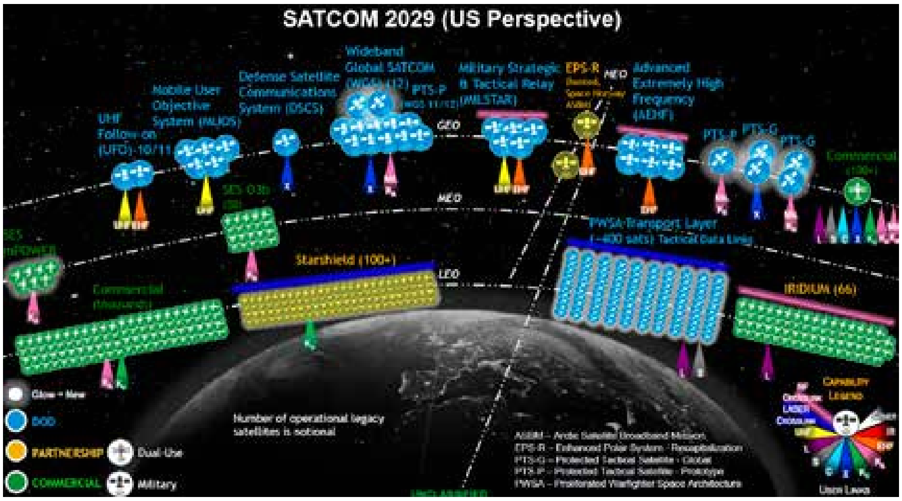

Figure 2. Multi-Orbit/Multi-Band architecture considerations. (Figure provided by author.)

algorithms can caused delays, resulting in temporary communication blackouts. Incidents such as this underscored the importance of robust synchronization protocols and fail-safe mechanisms. This is extremely tough to orchestrate for operational users.

Adversaries with advanced capabilities, such as China and Russia, are actively developing sophisticated jamming techniques and cyberattack tools designed to disrupt multi-band and multi-orbit communications. These threats could force reliance on failover systems that may themselves be vulnerable to coordinated attacks. Furthermore, spectrum congestion poses another challenge, as adversaries could intentionally flood specific frequency bands, creating bottlenecks that undermine the effectiveness of transport-diverse systems.

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Anti-satellite weapons present an additional risk to multi-orbit systems. By targeting key satellites, adversaries could disrupt the redundancy promised by transport diversity. To mitigate these risks, systems must integrate advanced counter-jamming technologies, robust encryption, and predictive analytics. Furthermore, collaboration with allied nations to share spectrum and orbital resources can strengthen the resilience of these systems, making them more robust in the face of adversarial interference.

Next Generation of Tactical SATCOM Systems

The next generation of tactical SATCOM systems represents a significant leap forward in integrating multi-orbit and multi-band capabilities. These systems promise to simplify logistics and operations, offering seamless failover and robust performance in contested environments. However, the high initial and operational costs of these systems present significant challenges.

Advanced components, such as software-defined radios and electronically steered antennas, require substantial research and development investments. As a result, the upfront cost of these systems could strain military budgets, particularly for large-scale deployments. Ongoing operational expenses—including software updates, cybersecurity patches, and specialized operator training—further complicate long-term budgeting.

To help decision makers better understand the financial implications, the following chart provides a snapshot of the costs associated with a generic multi-orbit terminal. These include the costs for hardware, service subscriptions, and operator training across various systems like Ka MEO, Ka medium Earth orbit, and Ku LEO (Starlink) systems.

Given the high operating costs, military planners must carefully evaluate procurement strategies. Decisions will

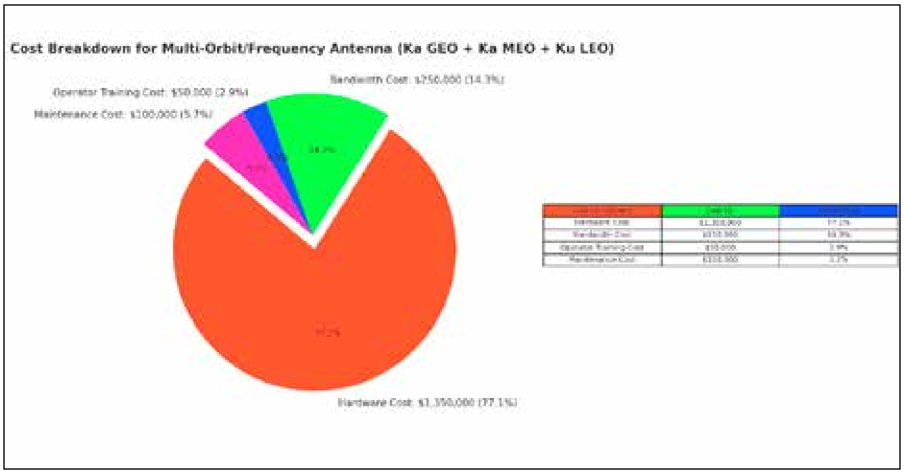

Figure 3. Source: Data based on industry benchmarks and 2024 market data for multi-orbit, multi-frequency antenna systems used in military and high-performance communication applications. The cost breakdown and visualizations presented in this chart are based on industry insights and estimated cost components for multi-orbit/frequency antenna systems, including hardware, bandwidth, operator training, and maintenance costs. These estimates reflect general trends for military-grade communication systems capable of handling Ka GEO, Ka MEO, and Ku LEO bands, with costs varying depending on system complexity, manufacturer, and specific application requirements. (Figure provided by author.)

need to balance system capabilities with budget constraints, prioritizing scalable or modular systems that offer long-term value. While these systems are ideal for high-priority missions, their complexity and cost could limit broader adoption. In some cases, simpler, orbit-specific platforms may provide a more cost-effective solution for less critical operations, reserving next-generation systems for scenarios requiring full-spectrum capabilities.

Modular designs present a viable solution. By developing platforms with orbit-specific capabilities that can be added or upgraded as needed, initial costs can be reduced, and adoption can be phased. Decision makers must also assess the return on investment to ensure that these systems align with actual operational demands and minimize resource inefficiencies.

Figure 4. Reducing the cognitive load does not mean we can have untrained operators. *(Photo provided by author.)*

SATCOM as a Managed Service (SaaMS)

Recently, there has been a conceptual shift toward SaaMS, which may revolutionize how military organizations access communication capabilities. Rather than investing in infrastructure, SaaMS allows for a subscription-based model that reduces the need for extensive hardware ownership, maintenance, and personnel resources. This approach provides scalability and operational flexibility, which are essential in high-demand environments.

However, while SaaMS can reduce capital expenditures, it may increase operational costs during periods of high usage. This requires careful planning to ensure that SaaMS complements, rather than replaces, owned infrastructure. A hybrid approach—combining owned infrastructure with SaaMS solutions—may offer the best balance between flexibility and control.

The successful adoption of SaaMS relies heavily on vendor management. Service-level agreements must clearly define performance standards, security protocols, and uptime guarantees. Accountability is essential to ensuring that commercial providers meet the stringent requirements for mission-critical operations. Additionally, SaaMS introduces risks such as vendor lock-in, which could limit flexibility. To mitigate these risks, organizations should consider diversifying providers and maintaining a certain level of owned infrastructure.

Another critical consideration is security. While commercial providers often offer strong encryption and cybersecurity measures, these must meet military-grade standards to prevent vulnerabilities. By integrating AI-driven resource allocation systems, SaaMS could dynamically prioritize bandwidth and capabilities based on realtime operational requirements, ensuring optimal performance even in high-demand scenarios.

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Balancing Capability with Simplicity

While simplifying SATCOM systems can reduce operator cognitive load, it comes with its own set of challenges. Overreliance on automation, for instance, could leave operators unprepared for unexpected failures. In situations where automated systems fail, operators may struggle to restore critical communications, delaying mission success.

To avoid this, training programs should emphasize manual override options and ensure operators are equipped to handle complex situations. By simulating real-world conditions, training can help operators gain the confidence and skills necessary to adapt quickly during unexpected disruptions.

Automation should enhance human decision making, not replace it. Providing operators with layered access to system functionalities—basic controls for general users and advanced features for specialists—can help strike a balance between simplicity and operational depth.

Ultimately, SATCOM systems should support human intervention, when necessary, with automation handling routine tasks, allowing operators to focus on higher-level decision-making and ensuring reliable communications under any circumstance.

Considerations for Decision Makers

To build truly resilient SATCOM networks, modularity plays a crucial role. Modular systems, where individual components can be easily replaced or upgraded, offer significant advantages in terms of both adaptability and cost-efficiency. This approach has proven successful in the aerospace industry for avionics systems and can similarly benefit SATCOM systems. By adopting modular designs, operators can minimize downtime and ensure continuous operational adaptability, making systems more responsive to changing demands and environments.

One of the most significant factors influencing military capable SATCOM systems today is *WGS certification with Delta-8*, which introduces new challenges for terminal manufacturers. Any significant updates to SATCOM systems that could affect radio frequency patterns require manufacturers to redesign and validate their hardware to meet these stricter requirements. As a result, the development and production costs increase, and there is additional lifecycle costs associated with ensuring ongoing compliance with future revisions of the Delta-8 standard.

For decision makers, achieving Delta-8 certification is essential for ensuring interoperability across military and allied networks. However, this certification is not a one-time process. It involves not only adapting to the new technologies but also maintaining continuous compliance with future changes. This means that terminal manufacturers must be able to upgrade or replace individual components as new WGS standards emerge. Modular designs offer an ideal solution to this challenge, allowing for adaptability and minimizing downtime while ensuring that systems stay compliant with the latest requirements.

In addition to meeting Delta-8 certification, SATCOM systems must also integrate advanced cybersecurity measures and counter-jamming technologies to protect against evolving threats. These systems must be robust enough to withstand increasingly sophisticated attacks, which requires manufacturers to embed security features deeply into the system's design from the outset.

Another crucial consideration is the adoption of *iterative prototyping* in operational settings. By testing systems in real-world environments, organizations can identify vulnerabilities early and optimize the design before large-scale deployment. This approach helps to reduce the risk of costly retrofits and ensures that the systems are better suited to dynamic operational conditions, making them more resilient when deployed in the field.

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Diversifying suppliers is also an effective strategy for building resilient SATCOM networks. A multi-vendor approach not only fosters innovation but also ensures supply chain stability. In periods of disruption or high demand, relying on a diverse set of suppliers reduces the risk of vulnerabilities and ensures that the system can continue to function without interruption.

Comprehensive *training programs* are equally essential for preparing operators to handle the complexity of advanced SATCOM systems. These programs should not only teach operators how to use the systems effectively but also ensure that they understand their limitations and potential failure modes. By equipping personnel with the knowledge and skills needed to respond quickly to unexpected challenges, organizations can maintain operational continuity and minimize the impact of system failures.

Finally, the integration of *AI-driven analytics* into SATCOM networks allows for realtime data analysis, which is vital for prioritizing bandwidth and processing power based on mission requirements. This dynamic resource allocation ensures that SATCOM systems can adapt to changing operational demands with precision, making them more efficient and effective in meeting mission-critical objectives.

By considering these factors—modularity, Delta-8 certification, iterative prototyping, supplier diversification, comprehensive training, and AI-driven analytics—decision makers can ensure that SATCOM networks remain resilient, adaptable, and optimized for the evolving demands of future conflicts. This comprehensive approach will help SATCOM systems not only withstand stress but also improve under it, ensuring continuous operational continuity and adaptability in an ever-changing environment.

Conclusion

For the U.S. military and Marine Corps decision makers, building a resilient SATCOM network is essential to maintaining operational superiority in a rapidly evolving and contested environment. Beyond traditional redundancy and failover mechanisms, resilient systems must be capable of not only withstanding stress but also adapting and improving in real time. By integrating modular designs, iterative feedback loops, and hybrid operational models, SATCOM networks can evolve to meet the unpredictable demands of modern military operations. These strategies ensure that SATCOM systems remain not only resilient but agile—enabling sustained, mission-critical communications in the face of adversarial interference, cyber threats, and operational disruptions. Prioritizing these principles will ensure that Marines have a communications backbone that thrives under pressure, maintains mission continuity, and remains adaptable to the complex challenges of future conflicts.

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