SYM-AM-26-149

EXCERPT FROM THE PROCEEDINGS

OF THE

TWENTY-THIRD ANNUAL ACQUISITION RESEARCH SYMPOSIUM AND INNOVATION SUMMIT

VOLUME III

"ACCELERATING WARFIGHTING CAPABILITIES"

Operationalizing Agility: Resolving the Titanium Wire-DED Certification Bottleneck and CMMC Economic Paradox to Preserve the Defense Industrial Base

Published: April 30, 2026

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Abstract

The United States Department of Defense (DoD) prioritizes accelerating warfighting capabilities, yet progress is obstructed by antiquated material specifications and costly cybersecurity mandates. This research analyzes two obstacles suppressing innovation and small business entry within the Defense Industrial Base (DIB): the regulatory barriers to titanium wire Directed Energy Deposition (wire-DED) additive manufacturing (AM), and the financial impact of Cybersecurity Maturity Model Certification (CMMC) compliance. Despite operational validation of wire-DED by four allied militaries for rapid expeditionary deployment, U.S. acquisition policy remains tethered to legacy frameworks.

Concurrently, CMMC compliance costs threaten to eradicate small manufacturing enterprises. This report details the metallurgical, logistical, and economic realities of defense manufacturing, utilizing primary National Science Foundation (NSF) Innovation Corps (I-Corps) data, culminating in a proposal for the Agile Manufacturing & Compliance (AMC) Framework.

By establishing a technical fast-track for wire-DED certification within the Engineering and Manufacturing Development (EMD) phase and a subsidized CMMC compliance safe harbor, the DoD can operationalize agility, scale Technical Data Packages (TDPs), and restore military readiness.

Introduction: The Defense Industrial Base at an Inflection Point

The United States defense apparatus operates within a geopolitical landscape characterized by escalating tension and rapidly advancing adversarial military capabilities. While the overarching strategic objective of the Department of Defense (DoD) is to accelerate warfighting capabilities, the foundational infrastructure required to sustain this power—the Defense Industrial Base (DIB)—is exhibiting severe structural vulnerabilities (Exiger, n.d.).

Recent defense readiness reports reveal a system under unprecedented strain; in 2024, the fleet-wide mission-capable rate of the United States Air Force (USAF) plunged to 62% (Defense News, 2025), leaving approximately 1,900 aircraft unready for operational deployment at any given moment (Air & Space Forces Magazine, 2025). This degradation in operational readiness is not a failure of aerospace engineering, but rather a cascading failure of supply chain logistics, manufacturing obsolescence, and rigid, exclusionary acquisition policies.

The military relies heavily on an aging inventory of platforms that require continuous, intensive sustainment. However, the legacy manufacturing processes required to produce spare components for these aircraft—particularly those constructed from critical titanium alloys—are slow, highly wasteful, and increasingly reliant on adversarial nations for raw material inputs. Concurrently, Additive Manufacturing (AM) technologies, specifically titanium wire Directed Energy Deposition (wire-DED), have emerged as mature, highly deployable solutions capable of bypassing these traditional logistical bottlenecks (Sciaky, n.d.). Yet, the rapid integration of such transformative technologies is actively suppressed by an over-reliance on legacy certification frameworks originally designed for 20th-century subtractive manufacturing.

Adding compounding friction to this crisis is the phased rollout of the Cybersecurity Maturity Model Certification (CMMC) 2.0 program. While robust supply chain cybersecurity is a non-negotiable imperative in the modern battlespace, the immense financial burden of achieving CMMC compliance is driving the very small machine shops and innovative startups that the military desperately needs out of the defense market entirely, creating a devastating “valley of death” for emerging technologies (Elevate Consult, 2026). This comprehensive white paper dissects the intertwined crises of titanium supply economics, aircraft sustainment logistics, additive manufacturing deployment, and CMMC compliance. By evaluating the metallurgical, technical, and financial realities of the modern DIB, the analysis uncovers the profound contradictions in current defense policy and offers a concrete roadmap to operationalize agility across the Major Capability Acquisition (MCA) pathway.

Empirical Findings from NSF Customer Discovery on Ti-6Al-4V Wire-DED and CMMC

Methodology

The customer-insight findings in this paper come from a National Science Foundation (NSF) Innovation Corps (I-Corps) regional program delivered through the University of Akron, which follows the standard Lean LaunchPad curriculum developed by Steve Blank. Our team began by capturing our hypotheses about titanium AM technologies (including wire Directed Energy Deposition (wire-DED)) and Cybersecurity Maturity Model Certification (CMMC) on a Business Model Canvas, then conducted structured "customer discovery" interviews with aerospace manufacturers, government laboratories, and additive manufacturing practitioners over several weeks. Each interview was logged and analyzed using the I-Corps process, and the canvas was iteratively updated based on the evidence. The synthesized patterns reported in the following section therefore reflect systematically gathered qualitative data, not anecdotal impressions.

Findings on Ti-6Al-4V Wire-DED and CMMC

As part of the NSF I-Corps program, structured interviews were conducted with aerospace and defense manufacturers, government laboratories, and AM practitioners to understand real-world barriers and opportunities for Ti-6Al-4V (Ti64) additive manufacturing. The results reveal five strategic patterns that directly reinforce the titanium wire-DED and CMMC paradox articulated in this paper.

Finding 1. Qualification is the dominant bottleneck.

Interviewees consistently identified part qualification—not machine speed or feedstock cost—as the primary constraint. Qualifying a single Ti64 part on a specific machine can cost on the order of $500,000 and take 6 months or more. Each significant change in machine, feedstock supplier, or geometry forces partial requalification. Stakeholders across the DoD and National Aeronautics and Space Administration (NASA) expressed a strong preference for process-based, outcome-based qualification, but current standards and process models lag behind this need. This mirrors the structure of CMMC Level 2 (L2) compliance: both qualification and cyber are large, front-loaded fixed costs that scale poorly for low-volume, high-mix Ti64 sustainment work.

Finding 2. Wire-DED is the right technical answer—but not yet the economic one.

Air Force Research Laboratory (AFRL) primarily uses powder-based AM equipment. Practitioners describe powder AM in unambiguous terms: it is hazardous, inefficient, and difficult to handle. Ti64 powder systems typically achieve effective material yields around 30% once "overspray" and limited re-use are accounted for, while wire-fed DED routinely approaches 90% material utilization and buy-to-fly ratios near 2:1—consistent with external Wire Arc Additive Manufacturing (WAAM) and wire-DED studies (Meltio, n.d.-b). Wire-DED also eliminates powder-specific explosion and inhalation risks and leverages mature welding wire supply chains. Interviewees widely agreed that for large Ti64 sustainment parts and future in-space manufacturing, wire-DED is more attractive than powder. However, they stressed that wire-DED is a near-net-shape process: it must be tightly coupled to Computer Numerical Control (CNC) machining and post-processing. Claims of "material agnosticism" were viewed skeptically; switching feedstock suppliers often requires new parameter development and quality campaigns.

Finding 3. Post-processing and Hot Isostatic Pressing (HIP) dominate cost.

The interviews confirmed that "printing is the easy part." More than half of total Ti64 AM part cost is typically consumed by machining, heat treatment, and finishing. For flight-critical Ti64 components, Hot Isostatic Pressing (HIP) is considered mandatory to close internal porosity and stabilize the microstructure. Any realistic AM business model and any DoD sustainment strategy must therefore integrate access to HIP and precision machining. This further increases the fixed-cost burden on small firms, which already face high qualification and CMMC L2 costs estimated at roughly $100,000–$300,000 in the first cycle.

Finding 4. The right entry point is non-critical DoD sustainment and future in-space manufacturing.

Interviewees identified two distinct market wedges for Ti64 AM. In the near term, DoD's most tractable use case is rapid replacement of non-safety-critical sustainment parts—simple components such as brackets, pins, and bushings for aging aircraft and ships. These parts are ideal candidates for a "Class C" category in the proposed Green Lane framework: low-risk components where wire-DED can be adopted quickly and field experience accumulated. In parallel, stakeholders highlighted in-space manufacturing as a longer-term opportunity. In vacuum and microgravity, Ti64 wire-DED combined with vacuum-compatible equipment offers a viable way to avoid launching large inventories of spares, whereas powder-based AM is impractical for orbital use.

Finding 5. Business models, universities, and Manufacturing Innovation Institutes (MIIs) are essential to survival.

Finally, the interviews underscored that building a company solely on DoD contracts is a "government revenue trap." Bid cycles of 18–24 months and sporadic purchase orders make it impossible for most Ti64 AM startups to survive on defense work alone. Instead, firms must balance commercial revenue with defense programs and rely on ecosystem partners. Academic collaborations solve the "garage-shop credibility" problem, provide access to expensive HIP and AM equipment, and open pathways to governmental funding. At the same time, participants stressed a severe gap in AM training and standards. They expressed strong preference for transparent Standard Operating Procedures (SOPs), open property datasets, and publicly vetted methodologies over proprietary "black box" claims.

Collectively, these empirical findings reinforce the central thesis of this paper. Ti64 wire-DED is technically aligned with DoD’s needs for rapid, safe, and efficient titanium manufacturing, yet it is trapped behind a stacked barrier of per-part qualification, mandatory HIP and post-processing infrastructure, and CMMC compliance overhead. Without process-based qualification, shared CMMC enclaves, and ecosystem support, the small businesses best positioned to deliver Ti64 wire-DED capability cannot rationally participate in the DIB.

Metals in Defense Manufacturing: A Cross-Modality Analysis

To understand the systemic bottlenecks in the DIB, one must first examine the elemental requirements of modern military hardware. Defense manufacturing relies on a broad spectrum of critical minerals and high-performance alloys, each selected for precise mechanical properties tailored to the extreme operating environments of the Army, Navy, Air Force, Marine Corps, and Space Force (NATO, 2024). Across all modalities, advanced weapon systems demand materials that balance structural integrity, thermal resilience, and weight. Aluminum alloys are extensively utilized in tactical missile systems and legacy airframes. Cobalt and nickel-based superalloys are critical for high-temperature applications, including jet engine turbine blades and submarine components. Refractory metals are increasingly required for next-generation hypersonic glide vehicles.

Despite the utility of these elements, titanium remains the undisputed “metal of choice” across the defense sector. The Navy utilizes titanium extensively in submarine hulls and seawater piping systems due to its absolute immunity to saltwater corrosion. The Army integrates titanium into lightweight combat vehicle armor and artillery systems. However, it is the aerospace sector that drives the most critical demand. Titanium’s exceptional strength-to-weight ratio and ability to withstand extreme aero-kinetic heating make it the foundational material for modern airframes, landing gear, and structural fasteners (Carpenter Technology, n.d.).

Titanium Metallurgy: Commercially Pure versus Ti-6Al-4V

Within the defense industry, titanium is primarily utilized in two distinct metallurgical categories: Commercially Pure (CP) Titanium and alloyed titanium, predominantly Ti-6Al-4V (commonly known as Ti64 or Grade 5).

Commercially Pure Titanium (CP Ti)

Commercially Pure Titanium (Grades 1 through 4) consists of 99% pure titanium, with variations in mechanical properties dictated by trace amounts of interstitial elements, primarily oxygen and iron. CP titanium is characterized by its excellent formability, high ductility, and supreme corrosion resistance, achieved via a naturally forming, self-healing oxide layer. Grade 1 is the softest and most ductile. Grade 2 is considered the industry “workhorse” for chemical processing and non-structural maritime applications. Grade 4 possesses the highest tensile strength among the unalloyed grades (approximately 80,000 psi or 550 MPa). However, CP titanium is generally not heat-treatable and lacks the shear strength and fatigue resistance required for extreme aerospace load-bearing applications.

Titanium Alloy Ti-6Al-4V (Ti64)

To meet the rigorous demands of military aviation, metallurgists developed Ti-6Al-4V, an alpha-beta alloy containing 6% aluminum and 4% vanadium. The strategic addition of aluminum stabilizes the alpha crystalline phase and dramatically increases the material’s strength-to-weight ratio, while vanadium stabilizes the beta phase, improving the alloy’s forgeability and thermal stability. Ti64 boasts a minimum tensile strength of approximately 130,000 to 138,000 psi (895 MPa), significantly outperforming even the strongest CP titanium grades (Carpenter Technology, n.d.). Furthermore, unlike CP titanium, Ti64 is fully heat-treatable, allowing engineers to finely tune its microstructure for specific high-stress applications. This unparalleled combination of attributes makes Ti64 the undisputed material of choice for highly stressed aerospace components, accounting for over 70% of all titanium alloys melted globally.

Table 1: Metallurgical Comparison of CP Titanium and Ti64

Property	**Commercially Pure Ti (Grade 4)**	**Ti-6Al-4V (Grade 5 / Ti64)**
Tensile Strength	~80,000 psi (550 MPa)	~138,000 psi (895 MPa)
Ductility (Elongation)	~15%	~10–14%
Heat Treatable	No	Yes (Annealing, Solution Treating)
Corrosion Resistance	Excellent	Very Good
Fatigue Resistance	Moderate	High
Primary Defense Uses	Marine environments, chemical tanks, low-stress piping	Jet engines, landing gear, airframes, missile casings

While Ti64 offers superior mechanical properties, its low thermal conductivity and high chemical reactivity make it notoriously difficult to machine using conventional methods, directly contributing to vast amounts of scrap waste (PMC, 2023).

The Global Titanium Supply Chain and U.S. Vulnerabilities

The United States currently possesses zero domestic production capacity for commercial titanium sponge, having shuttered its last remaining facility in 2020. As a result, the U.S. defense industry is 100% import-reliant for this foundational precursor, sourcing the vast majority of its titanium sponge from Japan, supplemented by Kazakhstan and Saudi Arabia (Bureau of Industry and Security, 2025). Globally, the titanium sponge market is heavily dominated by strategic adversaries. The People’s Republic of China is the world's largest producer, accounting for approximately 58% of global production capacity. The Russian Federation, driven by the state-owned VSMPO-AVISMA corporation, also commands a massive share of the high-end aerospace titanium market. This dependence exposes the U.S. defense sector to devastating supply shocks.

While the United States lacks sponge production, it maintains a robust mid-stream manufacturing base. The reliance on imported sponge makes the reclamation of domestic titanium scrap an issue of paramount strategic importance. During traditional manufacturing, massive quantities of titanium are machined away as swarf. The United States relies on specialized recycling facilities, such as IperionX, backed by DoD Industrial Base Analysis and Sustainment (IBAS) funding, to convert 100% recycled titanium scrap directly into titanium feedstock for additive manufacturing, effectively bypassing the vulnerable Kroll sponge process (IperionX, 2026).

Conventional Manufacturing versus the Additive Imperative

The Inefficiencies of Subtractive Manufacturing

The production of titanium components has historically relied on billet machining, casting, and forging. While these methods offer superior dimensional precision, they are extraordinarily wasteful. The critical metric defining this inefficiency is the Buy-to-Fly (BTF) ratio—the ratio of the mass of raw material purchased to the mass of the final part installed on the aircraft. The aerospace industry average BTF ratio for conventionally machined titanium parts ranges from 11:1 to as high as 20:1 (ResearchGate, n.d.). This dictates that between 90% and 95% of the highly strategic, imported titanium is systematically milled away into scrap.

The Additive Manufacturing Solution

To break the reliance on foreign titanium sponge, the defense sector is pivoting toward AM. The most profound immediate advantage of AM is the radical reduction in the BTF ratio. By building components layer-by-layer to a near-net shape, AM processes drop the titanium BTF ratio from the subtractive average of 11:1 down to approximately 1.5:1, equating to an up to 90% reduction in raw material waste (ResearchGate, n.d.).

Evaluating Additive Manufacturing Technologies for Metals

As validated by the NSF I-Corps interviews, the defense AM market is fractured across distinct technologies, each with significant operational differences.

Powder-Based Systems

Laser Powder Bed Fusion (LPBF) and Laser Powder-Directed Energy Deposition (LP-DED): While LPBF offers exceptional resolution, build volumes are heavily restricted. LP-DED systems blow fine metal powder through a nozzle into a laser-generated melt pool. Primary research indicates that powder DED suffers from severe material inefficiency, with catchment efficiency ranging from only 40% to 70%.

Hazards of Titanium Powder: The NSF I-Corps interviews explicitly highlighted that “dealing with powder sucks.” Titanium powder (<45 microns) is highly reactive and dangerously pyrophoric (Metal AM, n.d.). It poses severe risks of combustible dust explosions and requires hermetically sealed enclosures and specialized hazardous material (HAZMAT) protocols.

Wire-Based Systems

Wire-Directed Energy Deposition (wire-DED) processes feed a solid metal wire into a focused heat source. As validated by NSF findings, wire-DED offers up to 90% material yield and eliminates all pyrophoric powder hazards (Sciaky, n.d.).

Laser Wire-DED (LW-DED): Laser wire-DED utilizes precision lasers to melt the wire feedstock. It operates in an open environment with localized inert gas shielding, offering the optimal balance of high deposition rates, excellent geometric accuracy, and low thermal distortion (Meltio, n.d.-a). Because the feedstock is standard, globally commoditized welding wire, the material costs are significantly lower than highly refined AM powders.

Aviation Sustainability

The inefficiencies of legacy manufacturing directly fuel the current crisis in military aviation sustainment. The U.S. Air Force operates a sprawling fleet of aging aircraft. Sustaining these legacy aircraft is severely hindered by “diminishing manufacturing sources,” colloquially known as “vanishing vendor syndrome" (GAO, 2024). Consequently, out of approximately 35,000 total National Stock Number (NSN) solicitations, the Defense Logistics Agency (DLA) currently faces an estimated 15,000 for which absolutely no vendors are bidding (BidLink Defense Industry News, 2026). While not all 15,000 NSNs are aviation-specific, this massive shortfall includes critical structural panels, access doors, and hydraulic components across multiple domains. To maintain minimum mission readiness, the DoD aviation depots are forced to cannibalize parts—removing functional parts from one aircraft to repair another, a practice that is detrimental to personnel morale and leaves multimillion-dollar airframes permanently grounded.

Operationalizing Additive Manufacturing: Decentralized vs. Centralized Models

To bridge the gap between vanishing vendors and sustainment mandates, the DoD must operationalize wire-DED. The market supports two distinct business models. Companies like Norsk Titanium and GKN Aerospace operate primarily under a centralized parts manufacturing model. Utilizing massive, highly controlled, and proprietary additive cells, these firms act as tier-1 suppliers, printing and selling finished structural components directly to major OEMs like Boeing and Airbus. While this reduces the BTF ratio, it effectively replaces one centralized supplier with another, failing to decentralize capability down to the warfighter at the edge of the battlespace.

Conversely, wire DED AM equipment manufacturers champion a decentralized model through the direct sale of versatile, commercially available wire-DED equipment (Meltio, n.d.-a). Meltio has commercialized a patented multi-laser deposition head utilizing a coaxial wire feed. These print heads can be integrated directly into existing CNC milling machines, creating hybrid manufacturing centers. By relying on generic welding wire, these systems can be publicly purchased and adopted by small U.S. businesses and military depots. As validated by the NSF I-Corps study, producing parts via wire-DED is a near-net-shape process that requires post-processing. Over 50% of the cost is consumed by this phase. To achieve aerospace-grade mechanical properties, Ti64 AM parts must be subjected to HIP to collapse internal voids and completely seal argon-induced porosity (NIST, n.d.).

Vignette: Practical Validation of Expeditionary Manufacturing on the USS *Somerset*

Successful defense acquisition must be grounded in operational evidence, not laboratory promise. For wire-DED, that evidence exists—and it comes not from a single demonstration, but from four distinct allied militaries that have independently validated the technology for real-world, contested-environment logistics.

The operational record is substantial. The United States Navy (USN) deployed onboard metal three-dimensional (3D) printing aboard USS *Bataan* and USS *Somerset*, successfully manufacturing critical components in 5 days rather than weeks, achieving an over 80% reduction in lead time (Navy.mil, 2024). The French Navy validated wire-DED during Exercise Ursa Minor 2024 aboard the aircraft carrier Charles de Gaulle (Meltio, n.d.-c). Spain’s Ministry of Defense initiated a 4-year agreement to deploy wire-DED technology across its Army, Navy, and Air Force. And in 2025, the Republic of Korea Marine Corps certified wire-DED for operational use.

Reinforcing these allied commitments, the DoD designated Meltio—a leading wire-DED equipment manufacturer—as a strategic partner under the XtechInnovation program. The most instructive demonstration of this capability occurred during the 2024 Rim of the Pacific (RIMPAC) exercise. Aboard USS *Somerset*, a critical component of the ship's reverse osmosis pump suffered a catastrophic failure. Without that pump, the vessel could not generate potable water—a condition that threatened to abort a major international deployment and remove the ship from the operational theater entirely (Navy.mil, 2024).

Under a traditional DLA procurement timeline, sourcing a replacement cast steel component would have required weeks or months, an unacceptable delay in an active exercise environment. Somerset was equipped with the Snowbird Additive Mobile Manufacturing Technology (SAMM Tech) platform—a self-contained shipping container integrating a Meltio wire-DED metal printing head with a FANUC-controlled Computer Numerical Control (CNC) machining system. Using this "factory at sea," the crew additively manufactured and machined the replacement component within hours. The ship returned to full operational status, completed its mission, and demonstrated in a single real-world event what the multi-nation validation record confirms more broadly: Wire-DED is not an emerging technology awaiting proof of concept. It is an operationally proven capability, deployed today, that the U.S. acquisition system has yet to fully institutionalize.

Scaling Through America Makes

Transforming a naval vessel into a "factory at sea" fundamentally alters military logistics by replacing the physical transport of parts with the digital transmission of Technical Data Packages (TDP). Because aviation and naval platforms are shared across allied militaries, a validated TDP library allows deployed assets to instantly materialize hardware. Furthermore, these exact same TDPs can be shared across the smaller domestic DIB through Manufacturing Innovation Institutes (MIIs) like the America Makes Core platform. By democratizing access to validated print instructions, the DoD can allow the small business DIB to rapidly ramp up manufacturing during surge demand.

The Certification Bottleneck: EMD Phase and MMPDS

Despite the operational success demonstrated aboard USS *Somerset*, the integration of titanium additive manufacturing into U.S. military aviation remains constrained less by technical feasibility than by the structure of certification during the Engineering and Manufacturing Development phase of the acquisition life cycle. Aerospace engineers appropriately rely on the Metallic Materials Properties Development and Standardization (MMPDS) Handbook as the principal source of statistically based metallic material allowables (SAE International, 2025).

Yet, when this framework is applied to additive manufacturing, it necessarily demands rigorous control of feedstock, machines, process variability, and application-specific substantiation before material-property data can be translated into approved design use. The result is that even where a Ti-6Al-4V component can be produced rapidly and repeatably, the evidentiary burden required to qualify the material-process-application combination often remains too costly, too slow, and too narrowly tailored to support responsive sustainment. From an acquisition perspective, this creates a persistent asymmetry between manufacturing capability and fielding authority: a supplier may be able to fabricate a needed legacy aircraft bracket within hours, yet the pathway to certification can still delay operational use for months.

CMMC 2.0: Cybersecurity Mandates and the Economic Paradox

Adding to the certification bottleneck is the Cybersecurity Maturity Model Certification (CMMC). The DoD initiated CMMC to protect Controlled Unclassified Information (CUI) and Federal Contract Information (FCI). Under CMMC 2.0, any contractor handling CUI—including digital TDPs—must achieve CMMC Level 2 certification, aligning with the 110 security controls in NIST SP 800-171 (DoD CIO, n.d.).

The True Cost Burden on Small and Mid-Sized Machine Shops

The financial impact of CMMC 2.0 on small to medium-sized businesses (SMBs) is catastrophic, particularly given that SMBs constitute 73% of the DIB (Elevate Consult, 2026). While the DoD estimates assessment costs at approximately $104,670, this figure critically excludes vital implementation and hardware expenses (Totem Technologies, 2026). Extensive market studies reveal that the realistic first-year spend to achieve CMMC Level 2 compliance ranges from $98,000 to $305,000 (Powered by 1TEN, 2026). For a representative small business, the DoD projects a comprehensive 3-year total cost of approximately $487,970, factoring in implementation, recurring maintenance, and audit fees.

Table 2: CMMC 2.0 Cost Analysis by Organization Size

Organization Size (Employees)	Estimated Implementation Cost	C3PAO Assessment Fee	Time to Readiness
Small (< 50)	$75,000 - $300,000+	$30,000 - $50,000	12 to 18 months
Medium (50 - 200)	$100,000 - $500,000+	$50,000 - $80,000	12 to 18 months
Large (200+)	$500,000+	$80,000 - $150,000+	18 to 36 months

This cost is driven by several intensive factors:

- Gap Assessment: $3,500 to $20,000.
- System Security Plan (SSP) & Policy Documentation: $15,000 to $60,000.
- Consulting Fees (RPO/vCISO): $250 to $400 per hour, often totaling $50,000 to $300,000 for full engagement.
- Technology & Infrastructure Upgrades: Security Information and Event Management (SIEM) software licensing runs $5,000 to $30,000+ annually.
- C3PAO Audit Fees: $30,000 to $150,000+ depending on company size.
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Example 1: The CMMC Economic Paradox (Simulated Small Business Impact)

- Annual Revenue: $1,500,000
- Typical Tier 3 AM shop Net Profit Margin (Pre-CMMC): 15%
- Industry average Net Profit (Pre-CMMC): $225,000
- Est. CMMC 1st Year Cost: ($150,000)

- Remaining Profit: $75,000 (66% reduction in profit)

Result: The CMMC compliance costs can consume an entire year's profit for contractors with DoD revenue under $500,000.

Relying on 18-to-24-month DoD bid cycles is financially unsustainable. For a small manufacturer generating $2 million in total revenue, where defense subcontracts account for only $400,000, investing $150,000 to protect that revenue stream is mathematically irrational; the business will simply abandon the DIB and focus on commercial clients. Industry analysts predict that between 15% and 20% of the DIB will exit the defense market entirely by the end of 2026.

Strategic Competition: Adversarial Agility and Partner Nations

The U.S. defense sector is starkly juxtaposed against the aggressive agility of its strategic adversaries. China has explicitly embedded additive manufacturing into its "Made in China 2025" plan. Supported by heavy state funding, Chinese venture capital in AM reached $1.95 billion between 2022 and 2024, enabling them to capture nearly half of global LPBF system sales and secure supply chain independence (IMTS, 2026). Concurrently, while CMMC is a domestic U.S. framework, the DoD is actively working to establish reciprocity with AUKUS (Australia, UK, US) and NATO cybersecurity standards. However, if partner nations heavily subsidize their domestic manufacturers' cybersecurity compliance while the United States does not, foreign entities will easily outcompete American SMBs for DoD contracts, further hollowing out the domestic homeland DIB.

Conclusion: The Agile Manufacturing & Compliance (AMC) Framework

To resolve these interconnected crises, the DoD must adopt the Agile Manufacturing & Compliance (AMC) Framework, a Dual-Track Acquisition Reform strategy designed to integrate seamlessly into the Adaptive Acquisition Framework (AAF). Rather than relying on outdated procurement methodologies, this approach leverages Technical Data Packages and advanced wire-DED manufacturing to bypass traditional bottlenecks. By implementing performance-based Developmental Test and Evaluation (DT&E) qualification and subsidizing CMMC C3PAO costs via Defense Production Act Title III funds, the DoD can ensure the retention of the DIB and fully operationalize agility.

Track 1: Technical Fast-Track for Titanium Wire-DED Adoption

The DoD must aggressively modernize its approach to part qualification during the EMD phase. The rigid adherence to per-machine, process-based statistics within MMPDS Volume II must be reformed to allow for a performance-based fast-track. If a generic wire-DED titanium component mathematically and physically meets the ultimate tensile, fatigue, and geometric tolerances of the original legacy component, it must be cleared for Developmental Test and Evaluation (DT&E) flight activities.

Track 2: Subsidized Compliance Safe Harbor for Small Innovators

The DoD must directly intervene in the economics of CMMC 2.0 to prevent the catastrophic exit of over 30,000 small businesses from the DIB. The government must establish a subsidized "Safe Harbor" mechanism—shifting from per-company CMMC infrastructure to shared secure enclaves—so the cyber fixed cost is amortized across many firms.

By institutionalizing titanium wire-DED and aligning regulatory requirements with the realities of small-business participation, the United States can reinforce industrial resilience, sustain aviation & fleet readiness, and sharpen warfighting capabilities.

Abbreviations

n.d.: no date
AAF: Adaptive Acquisition Framework
AM: Additive Manufacturing
AMC: Agile Manufacturing & Compliance
BTF: Buy-to-Fly
C3PAO: Certified Third-Party Assessment Organization
CMMC: Cybersecurity Maturity Model Certification
CNC: Computer Numerical Control
CP: Commercially Pure
CUI: Controlled Unclassified Information
DED: Directed Energy Deposition
DIB: Defense Industrial Base
DLA: Defense Logistics Agency
DoD: Department of Defense
DT&E: Developmental Test and Evaluation
EMD: Engineering and Manufacturing Development
FCI: Federal Contract Information
HIP: Hot Isostatic Pressing
HAZMAT: Hazardous Material
IBAS: Industrial Base Analysis and Sustainment
LPBF: Laser Powder Bed Fusion
LP-DED: Laser Powder Directed Energy Deposition
LW-DED: Laser Wire Directed Energy Deposition
MCA: Major Capability Acquisition
MII: Manufacturing Innovation Institute
MMPDS: Metallic Materials Properties Development and Standardization
NASA: National Aeronautics and Space Administration
NATO: North Atlantic Treaty Organization
NSF: National Science Foundation
NSN: National Stock Number
OEM: Original Equipment Manufacturer
RIMPAC: Rim of the Pacific
SAMM: Snowbird Additive Mobile Manufacturing
SIEM: Security Information and Event Management
SMB: Small to Medium-Sized Business
SOP: Standard Operating Procedure
SSP: System Security Plan
TDP: Technical Data Package
USAF: United States Air Force

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