Managing Feedstocks for Additive Manufacturing

in a Tactical Environment: Supply Chain Security, Material Selection, Storage, and Resupply Doctrine for Forward-Deployed AM Operations

ASSESSMENT SCOPE

This paper examines the feedstock problem created by expanding forward-deployed additive manufacturing: what materials are required, where they originate, how they degrade in tactical environments, how they must be stored and handled, how they are resupplied in contested logistics conditions, and what the FY2026 NDAA's adversary-nation restrictions mean for the feedstock supply chain that tactical units will depend upon. The analysis draws on DoDI 5000.93, the DoD AM Roadmap, ASTM feedstock standards development, Army Research Laboratory materials science findings, USNI Proceedings shipboard AM analysis, and the operational models of the Marine Corps XFab, Army R-FAB, DEVCOM ARL Livingston demonstration, and allied field exercises.

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This paper draws exclusively on publicly available and officially released sources. No classified information is referenced.

Executive Summary

The expansion of additive manufacturing to the forward line of troops, directed by the Secretary of the Army in April 2025 and codified through the Military Additive Manufacturing Summit 2026 as a target for operational unit fielding by December 2026, has produced a logistics problem the institutional conversation about AM has not yet resolved: the feedstock problem. A 3D printer without feedstock is inoperable. A printer with degraded, moisture-contaminated, or thermally compromised feedstock produces parts that fail. A printer supplied by a feedstock chain concentrated in adversary nations creates a strategic vulnerability that FY2026 NDAA Section 849 begins to address for hardware, but does not yet address for materials.

The feedstock problem has three dimensions. The first is material science: each category of AM feedstock, from commodity polymers through carbon-fiber-reinforced nylons to cold spray metal powders, has specific environmental sensitivities that the tactical edge exposes at every point. Humidity, temperature extremes, ultraviolet exposure, shock, vibration, and contamination all degrade feedstock quality and produce parts with unpredictable mechanical properties. Army Research Laboratory has quantified some of these effects precisely: exposure to high humidity increased the critical adhesion velocity of aluminum cold spray powder by more than 125 meters per second. Nylon and carbon-fiber-reinforced polymer filaments absorb ambient moisture and produce porous, delaminated prints when stored in unsealed containers.

The second dimension is supply chain: where does feedstock originate, and how secure is that chain in a contested environment? The global PETG filament market includes significant Chinese manufacturing capacity. Specialty metal powders for cold spray AM involve supply chains that pass through Chinese raw material processing for critical precursor materials. The FY2026 NDAA's Section 846 prohibition on procuring molybdenum, gallium, and germanium from non-allied nations signals Congressional awareness that materials supply chains are strategic vulnerabilities; no equivalent provision yet addresses the polymer feedstock supply chain on which tactical AM depends most immediately.

The third dimension is logistics doctrine: how is feedstock resupplied in a forward-deployed AM operation, what is the packaging and storage standard, and who is responsible for maintaining feedstock stock levels as a sustainment function? None of these questions has been answered in current AM policy. DoDI 5000.93 addresses the digital thread and cybersecurity dimensions of AM. It does not establish a feedstock logistics standard, assign storage requirements by material type, or define resupply responsibility within the sustainment structure.

> **THE FEEDSTOCK IMPERATIVE**
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> The Secretary of the Army's April 2025 directive to extend AM to operational units by 2026 is not a printer procurement problem. It is a feedstock problem. Printers can be procured from NDAA-compliant manufacturers. Feedstock must be produced in sufficient quantities to sustain operations, stored under conditions that preserve material properties across the range of tactical environments, resupplied through a logistics pipeline that functions in contested environments, and sourced from supply chains that are not vulnerable to adversary interdiction. Without a feedstock doctrine to match the printer fielding directive, the AM capability the Army is building will be constrained by the weakest link in the material supply chain.

1. The Feedstock Taxonomy: What Tactical AM Requires and Why Each Category Presents Distinct Challenges

1.1 Tier 1 Polymers: PETG, ASA, ABS, and TPU

The most widely used feedstock at platoon and company level for Group 1 FPV airframe production is fused filament fabrication polymer: PLA, PETG, ASA, ABS, and TPU for flexible components. Each has distinct environmental sensitivities relevant to tactical storage. PLA softens at approximately 60 degrees Celsius, making it unsuitable for components exposed to solar heating in a vehicle interior, desert environment, or enclosed shelter. A PLA motor mount left in a vehicle cab in direct sun in a Middle Eastern operational environment may deform before the drone is fielded. PETG is the preferred general-purpose tactical filament: it is moisture-resistant relative to nylon, prints between 230 and 250 degrees Celsius, and has a heat deflection temperature of approximately 70 to 80 degrees Celsius. ASA is the outdoor-rated alternative, with UV resistance that PLA and PETG lack and a heat deflection temperature exceeding 95 degrees Celsius, making it the correct selection for structural components exposed to sustained direct sunlight.

The moisture sensitivity of hygroscopic polymers, particularly nylon, and to lesser degrees PETG and ABS, is the primary feedstock management challenge at the tactical edge. Filament that has absorbed ambient moisture produces parts with visible bubbling, stringing, and reduced layer adhesion. The resulting parts have unpredictable tensile strength and fatigue life. In a temperate climate at 60 percent relative humidity, an unsealed nylon spool left open will absorb sufficient moisture to degrade print quality within 24 to 48 hours. In a tropical environment at 85 to 90 percent relative humidity, degradation occurs within hours. The solution is sealed storage with active desiccant, a requirement that is not currently specified in any Army table of allowances or AM standard operating procedure.

1.2 Tier 2 Carbon-Fiber-Reinforced Polymers

Carbon-fiber-reinforced polymer filaments, including chopped-carbon nylon such as Onyx from Markforged and carbon-filled PA12 from multiple suppliers, provide tensile strength two to three times that of standard polymers. They are the correct material for Group 2 UAS structural components, motor mounts requiring vibration resistance, and wing sections bearing structural loads.

CFRP filaments present three tactical storage challenges beyond standard polymer management. First, the nylon matrix absorbs moisture more rapidly and severely than PETG or ASA: nylon-based CFRP must remain sealed with active desiccant from production through the moment of use. Second, the chopped carbon fiber content requires hardened steel nozzles, which wear faster than standard brass nozzles and are consumables the feedstock logistics system must track alongside filament. Third, continuous-fiber systems require managing a secondary fiber spool in addition to the matrix filament spool, doubling the storage complexity for a two-material system.

Army Research Laboratory's work on dual-material filaments addresses the expeditionary storage problem directly. Dr. Eric Wetzel's team at DEVCOM ARL developed a thermal draw process producing a dual-material filament with an ABS matrix and polycarbonate star-shaped core that can be used in a standard FFF printer to produce parts with mechanical properties competitive with injection-molded plastics. The ARL problem statement framing this research is the key doctrinal insight: the Army wants the ability to print parts in the field to simplify logistics by carrying digital part files instead of physical parts, but the technologies for

producing high-strength parts have not been practical in an expeditionary setting because their feedstocks can require specialized storage requirements that are impractical for forward deployment. Developing feedstocks with tactical-edge storage compatibility is as much a research priority as developing printers that operate in austere environments.

1.3 Cold Spray Metal Powders

Cold spray additive manufacturing uses high-velocity gas jets to propel metal powder particles at up to four times the speed of sound, bonding them through mechanical interlocking and metallurgical adhesion without high-temperature melting. The WarpSPEE3D printer demonstrated in the DEVCOM ARL Livingston, Tennessee field exercise of August 2024 uses aluminum powder as its primary feedstock; copper, titanium, and nickel alloy powders are used in CSAM applications for different structural and thermal requirements.

Metal powder feedstock presents the most demanding storage requirements of any AM material at the tactical edge. Army Research Laboratory research quantified the humidity sensitivity of aluminum powder precisely: even slight exposure to high levels of humidity increased the critical adhesion velocity by more than 125 meters per second, approximately 14 percent above the baseline bonding velocity under standard conditions. This increase means that humidity-exposed powder requires higher spray velocities to achieve equivalent bond quality; if the system is not recalibrated to compensate, the resulting part has degraded mechanical properties that are not visible to the operator. ASTM is developing standard WK83145 specifically to address this gap, providing methodology to assess flowability, spreadability, density, and composition changes from moisture exposure. Until that standard is published and adopted into DoD AM qualification frameworks, operators at the tactical edge have no standardized procedure for determining whether a powder lot has been compromised.

Beyond humidity, metal powder feedstock presents three additional tactical management challenges. The nitrogen gas required for WarpSPEE3D operation must be co-located with the printer, creating a pressurized vessel logistics requirement with its own storage, transport, and safety protocols. Fine metal powder presents an inhalation hazard requiring respiratory protection during handling, adding personal protective equipment requirements to the operator's kit list. And specialty metal powders for CSAM, including aluminum, copper, titanium, and nickel alloys, are sourced from a smaller supplier base whose supply chains involve raw material precursors subject to adversary-nation export controls.

THE ARL EXPEDITIONARY FEEDSTOCK PROBLEM STATEMENT

DEVCOM ARL's Dr. Eric Wetzel team framed the tactical feedstock challenge precisely in published research: the Army wants to print parts in the field to simplify logistics by carrying digital part files instead of physical parts, but to date, the technologies for producing high-strength parts have not been practical in an expeditionary setting. The printers are too large, energy-hungry, delicate or messy, and their feedstocks require specialized storage requirements.

This statement is both a limitation assessment and a research direction: the required feedstock for tactical AM is one that tolerates the environmental range the tactical edge presents, requires minimal specialized storage infrastructure, and can be handled safely by Soldiers with standard training. No currently fielded AM feedstock at Tier 2 or Tier 3 meets all three criteria simultaneously. Developing or qualifying feedstocks that do is a research priority that should sit alongside printer hardware development in the DoD AM investment portfolio.

2. Environmental Degradation: What the Tactical Edge Does to Feedstock

2.1 Humidity: The Primary Failure Mode Across All Material Tiers

The USNI Proceedings July 2024 analysis of shipboard AM, the most operationally proximate published assessment of AM feedstock management in a non-controlled environment, identifies climate control for feedstock storage as a fundamental operational requirement. The study notes that all AM equipment and feedstock requires storage space and, depending on the type of feedstock material and its sensitivity, such storage needs some form of climate control to maintain steady temperature and humidity levels, and that failure to maintain these variables could result in feedstock compromises that degrade the manufactured equipment.

The quantitative data on humidity-induced feedstock degradation provides specific planning parameters. For aluminum cold spray powder, a humidity exposure that produces surface hydroxide layers increases critical adhesion velocity by more than 125 m/s. For nylon-based polymer filaments, 24 to 48 hours of exposure at 60 percent relative humidity produces measurable print quality degradation. For metal powders, the MDPI Materials study on Al 5056 and tantalum powders found that environmental exposure produced inconsistent flowability and moisture content changes that are difficult to predict from powder morphology alone, making in-field quality assessment without standardized testing equipment problematic. The DoD Integrated AM Roadmap explicitly identifies thermal, humidity, and salt conditions as unique environmental factors requiring specific consideration for materials storage, handling, and AM processes in deployed and expeditionary environments. These assessments exist in policy documents. They have not yet been translated into storage standards or resupply requirements.

2.2 Temperature Extremes

Polymer filaments stored above 40 degrees Celsius experience accelerated moisture absorption in humid conditions and dimensional stability changes in dry conditions. PLA filament stored at 50 degrees Celsius in a dry environment will develop crystallinity changes that affect print quality. PETG and ASA are more thermally stable but still perform best when stored below 30 degrees Celsius. At the cold extreme, polymer filaments stored below minus 10 degrees Celsius become brittle and can fracture during spool handling or feeding through the extruder mechanism.

Cold spray metal powders must be brought to ambient temperature before use to prevent condensation when cold powder contacts warmer ambient air. The SPEE3D EMU expeditionary metal AM system validation confirms that the printer hardware operates in sub-zero conditions; the feedstock management protocol for cold-environment operations, which must address condensation on temperature-transitioned powder, is a distinct operational requirement that has not yet been specified. India's Project Prabal, which printed defensive structures at an altitude of 11,000 feet in a high-altitude, low-oxygen environment, demonstrates that AM hardware can operate at temperature extremes far beyond temperate assumptions; feedstock management protocols for those environments are a separate, unaddressed problem.

2.3 UV Exposure, Shock, Vibration, and Contamination

Ultraviolet radiation degrades the packaging of polymer filament spools, compromising the vacuum-sealed packaging that provides moisture protection. Standard commercial packaging, cardboard boxes, provides no UV protection and limited moisture resistance. Military packaging standards for filament feedstock should specify UV-opaque, moisture-sealed containers that survive field handling, vehicle transport, and outdoor storage. The commercial spool represents a logistics packaging specification mismatch with the operational environment.

Shock and vibration during vehicle transport affects metal powder feedstock in a specific way: settling and compaction of the powder bed in the storage container alters bulk density and flowability characteristics that the CSAM process relies on. Metal powders stored in partially filled containers and subjected to road march vibration will have compaction states that differ from manufacturer specifications, requiring assessment before use. Contamination of fine metal powder during handling in a tactical environment, through contact with dust, soil, or other particulates, alters composition and bonding characteristics. Handling protocols for metal powder at the tactical edge require personal protective equipment and clean-surface discipline that must be specified in operator training materials and validated in the MOS qualification process.

Exhibit 1 | AM Feedstock Environmental Sensitivity: Tactical Edge Storage Requirements by Material Tier

Material	Primary Failure Mode	Humidity Limit	Temperature Range	Storage Requirement	Estimated Resupply (Tier 1 FPV ops/week)
PLA (polylactic acid)	Thermal softening at 60C; moisture absorption; UV packaging degradation	Moderate: store sealed; 24-hr open exposure acceptable below 60% RH	Store below 30C; do not use if spool temp exceeded 50C	Sealed vacuum bag; dark storage; avoid vehicle cab solar exposure	1-2 kg (3-6 FPV frames); operationally impractical for most tactical environments due to heat failure
PETG	Moisture absorption producing porosity and surface finish degradation	Moderate: degrades after 48-72 hr open above 70% RH; store sealed with desiccant	Store 15-30C; stable to 80C in service	Sealed vacuum bag with desiccant packet; UV-opaque container for transport	1-2 kg (4-6 FPV frames); preferred Tier 1 general-use filament for most environments
ASA	UV degradation of part surface (negligible if stored correctly); moisture less severe than nylon	Low: tolerates 48+ hr open in most conditions below 80% RH	Store 15-30C; heat deflection 95C; UV stable in service	Sealed bag preferred; vacuum not required in dry climates	1-2 kg; recommended for outdoor structural components; superior UV resistance
Nylon / CFRP Nylon	Rapid moisture absorption producing	HIGH: degrades in 24 hr	Store 15-25C; avoid	Vacuum-sealed container with active silica gel at all times; heated dry box	0.5-1 kg; higher cost; requires dedicated dry storage capability at

Material	Primary Failure Mode	Humidity Limit	Temperature Range	Storage Requirement	Estimated Resupply (Tier 1 FPV ops/week)
(PA12, Onyx)	porosity, delamination, and stringing	open above 60% RH; 6-12 hr above 85% RH; must remain sealed until moment of use	thermal cycling	required in high-humidity environments; hardened steel nozzles as tracked consumable	every echelon
Aluminum cold spray powder (CSAM)	Humidity-induced hydroxide layer degradation; +125 m/s critical adhesion velocity increase per ARL research	HIGH: even brief high-humidity exposure causes measurable bond quality degradation	Room temperature; must be brought to ambient before use to prevent condensation	Sealed metal container; nitrogen purge storage for long-term; do not open above 80% RH or in rain	5-10 kg for structural metal components; nitrogen gas supply co-located; Tier 3 capability
Specialty metal powders (Cu, Ti, NiAl for CSAM)	Same as aluminum powder; contamination from field handling; PSD changes from vibration settling	HIGH: equivalent to aluminum powder requirements	Room temperature; vibration-isolated transport to preserve PSD	Sealed, labelled, vibration-resistant metal containers; PPE required; separate storage from flammables	2-5 kg depending on application; Tier 3 capability only

Sources: ARL Army.mil humidity research; ASTM WK83145; USNI Proceedings Shipboard AM (July 2024); MDPI Metals powder handling study; DoD AM Roadmap (America Makes, 2016)

3. The Supply Chain Problem: Where Feedstock Comes From and Where the Chain Is Vulnerable

3.1 The Polymer Filament Supply Chain

The global polymer filament market is dominated by Chinese manufacturers at the commodity end, European specialists at the performance end, and a small number of U.S.-based producers at the military-specification end. The PETG market, which represents the primary Tier 1 tactical feedstock, includes Chinese manufacturers accounting for a substantial share of global production. The global PETG market was valued at over $800

million in 2022 and is projected to grow at a compound annual growth rate of 6.5 percent through 2030, with Chinese manufacturers holding significant market share across the standard 1.75mm and 2.85mm filament formats that tactical AM equipment uses.

The FY2026 NDAA's Section 849 prohibition applies to AM machines, not feedstocks. There is no equivalent provision restricting the procurement of Chinese-manufactured polymer filament for DoD use. This gap is consequential: a unit operating a NDAA-compliant printer loaded with Chinese-manufactured filament has addressed the hardware compliance requirement but maintained Chinese feedstock supply chain dependency. In a deliberate denial scenario, adversary export restrictions on polymer precursor materials, analogous to China's December 2024 gallium export embargo, could constrain filament supply at the point where tactical AM capability depends on it most.

The practical near-term feedstock supply chain security action is to identify NDAA-compliant or allied-nation polymer feedstock suppliers at each material tier and establish purchase arrangements that create domestic or allied supply chain capacity. The U.S. polymer industry has the technical capability to produce PETG, ASA, nylon, and CFRP filaments at military-specification quality. The DoD's FY2024 AM expenditure of approximately $797 million, and the FY2026 budget commitment, represent demand signals large enough to support domestic or allied-nation specialty feedstock production investment through the Defense Industrial Base Fund authorities expanded by FY2026 NDAA Section 867.

3.2 The Metal Powder Supply Chain and Critical Material Dependencies

The metal powder supply chain for CSAM involves a more complex and strategically vulnerable set of material dependencies than polymer filament. Aluminum powder, the most common CSAM feedstock, is produced from primary aluminum through atomization processes. Specialty metal powders for high-performance CSAM applications, including nickel alloy powders for elevated-temperature components and titanium powder for structural aerospace applications, involve supply chains that pass through Russian and Chinese production at various processing stages.

The FY2026 NDAA's Section 846 specifically prohibits procurement of molybdenum, gallium, and germanium from non-allied foreign nations and authorizes production from recovered materials. China produces approximately 98 percent of the world's primary gallium. China's December 2024 embargo on gallium exports to the United States drove Rotterdam gallium prices to their highest level since 2011, reaching $687 per kilogram in May 2025, an increase exceeding 150 percent compared to pre-control prices. While gallium is not a primary CSAM feedstock, the Congressional action on gallium reflects an awareness of the material supply chain vulnerability that applies more broadly: specialty materials used in AM processes and in the electronics of AM systems are subject to the same adversary export control dynamics.

The Army's stated ambition to 3D print titanium parts at the organic industrial base, described by MG Lawrence and MG Lalor in the April 2025 Army Sustainment article on transforming Army sustainment through advanced manufacturing, highlights the strategic importance of a secure domestic titanium powder supply chain. That chain does not exist in sufficient quantity for large-scale tactical edge deployment, and the FY2026 NDAA's Section 220A program to additively manufacture metal parts, with a focus on long-lead-time and sole-source suppliers, creates a program hook for addressing it.

3.3 The Three-Tier Feedstock Availability Model

Tactical AM doctrine should specify a feedstock priority sequence for each material tier. The first priority is DLA-issued military-specification feedstock from pre-positioned stocks, which ensures material traceability

and quality control. The second priority is commercially procured feedstock from pre-qualified suppliers identified in the operational area before operations begin, analogous to host-nation support arrangements for fuel and water. The third priority is commercially sourced feedstock assessed for quality compliance by the unit AM operator using field acceptance procedures, analogous to the battle-damage check performed on Class IX parts before installation.

The Firestorm Labs xCell approach to feedstock supply chain management provides a model for the second priority tier: the xCell was designed specifically to use HP Multi-Jet Fusion feedstock that is globally available through industrial supply chains, a deliberate decision to avoid proprietary supply chains in operational environments. PETG filament in standard 1.75mm format is commercially available in virtually every country where U.S. forces operate, from South Korea and Japan through Europe to the Middle East. In a contested logistics environment where DLA resupply has been disrupted, a brigade's AM capability should be able to sustain basic polymer feedstock requirements through commercial procurement in the operational area, provided the unit has pre-identified commercial sources and has a quality acceptance procedure in place.

THE FEEDSTOCK AVAILABILITY PRINCIPLE

Tactical AM doctrine should establish a feedstock availability sequence: (1) DLA-issued military-specification feedstock from pre-positioned stocks; (2) commercially procured feedstock from pre-qualified suppliers in the operational area; (3) host-nation commercially sourced feedstock assessed for quality compliance using field acceptance procedures. This three-tier model mirrors the Class IX repair parts priority model and is the appropriate framework for managing feedstock continuity in contested logistics conditions.

The operational constraint on tiers two and three is quality verification. A filament spool purchased from a commercial vendor in an operational area may not meet the dimensional accuracy, material composition, or moisture content specifications that the unit's design files and printer settings assume. A simple field acceptance test procedure, using a short calibration print against a reference profile, should be part of the operator's standard operating procedure for any feedstock not issued from pre-qualified DLA stocks.

4. Logistics Doctrine: What Does Not Yet Exist

4.1 The Current Policy Gap

DoDI 5000.93 establishes that the DoD will use AM to transform maintenance operations and supply chains, and directs the Defense Logistics Agency to manage AM raw materials and ensure that supplier-generated AM data is provided to appropriate DoD organizations. The instruction assigns DLA responsibility for AM raw material management at the institutional level. It does not specify storage standards, environmental tolerance limits, packaging requirements, resupply priorities, or quality verification procedures for feedstock deployed at the tactical edge.

Current forward-deployed AM operations, from the R-FAB in South Korea to the Hawkeye Platoon of the 173rd Airborne Brigade in Georgia, manage feedstock through unit-level improvisation rather than standardized doctrine. The Hawkeye Platoon demonstrated drone production in a matter of hours at costs below $500 per airframe during the Agile Spirit 2025 exercise; feedstock management during that demonstration was an organic unit function without published standards. France's 17th Artillery Group

containerized mobile autonomous factory, producing 60 to 80 FPV drones per day in operation, manages filament stock as an organic logistics function without published equivalents in any NATO AM logistics doctrine. These models are operationally proven. None has been codified into a standard operating procedure, table of allowances entry, or Class IX resupply trigger that would enable the Army to sustain the capability at scale.

4.2 Feedstock as a Class IX Analog

The correct doctrinal framework for managing AM feedstock in the tactical logistics system is a Class IX analog: a supply category for repair parts and maintenance supplies that is tracked, managed, and resupplied through the property management and supply chain systems used for other consumable maintenance materials. Feedstock is functionally equivalent to welding wire, hydraulic fluid, and lubricants in the existing Class III and Class IX supply framework. It is a consumable material that supports maintenance operations, has defined storage requirements, has a consumption rate that can be estimated from production planning, and must be tracked at unit level to maintain operational capability.

Establishing feedstock as a Class IX analog requires four institutional actions. First, assign national stock numbers to standard military-specification feedstock materials at each tier: at minimum, PETG filament, ASA filament, CFRP nylon filament, aluminum CSAM powder, and standard nitrogen gas cylinders for CSAM nodes. Second, establish unit basic loads for feedstock based on the authorized production rate of each unit's AM equipment, specified by echelon: Tier 1 platoon level at approximately 10 kilograms of polymer; Tier 2 company to battalion level at 5 kilograms CFRP plus 10 kilograms polymer; Tier 3 brigade level at 20 kilograms polymer plus 20 kilograms metal powder plus nitrogen supply. Third, create DLA stock levels for feedstocks in forward pre-positioned supply sets comparable to Class IX pre-positioned repair parts. Fourth, establish a consumption reporting mechanism that triggers automatic resupply before feedstock falls below a defined threshold.

4.3 Storage Infrastructure Requirements at Each Echelon

Tier 1 polymer feedstock at platoon and company level requires a sealed, thermally managed storage container, equivalent in form factor to an ammunition can or a humidity-controlled pelican case, capable of maintaining filament below 30 degrees Celsius and below 40 percent relative humidity. Commercial solutions exist at the $30 to $100 price point: vacuum-sealed dry storage boxes with built-in hygrometers and active desiccant refresh can store two to four spools per container and are commercially available from multiple suppliers. The unit's authorized AM equipment list should include a specified quantity of these storage containers proportional to the print capability authorized.

Tier 2 CFRP and specialty polymer feedstock requires active desiccant management with monitoring: the storage box must include a hygrometer display, rechargeable silica gel desiccant, and a desiccant refresh schedule. This adds approximately $50 to $150 per storage unit over standard commercial vacuum bags and represents a small fraction of the cost of degraded CFRP filament producing inadequate structural parts.

Tier 3 cold spray metal powder storage at battalion and brigade level requires sealed metal containers with nitrogen purge capability for long-term storage, and a controlled environment at the containerized manufacturing node. The WarpSPEE3D system demonstrated at Livingston used nitrogen gas from a standard industrial supply. A portable membrane nitrogen generator drawing from an air compressor eliminates the pressurized cylinder logistics tail and should be evaluated as an authorized equipment item for Tier 3 cold spray AM nodes. The compressor-generator pairing is commercially available, transportable in a standard

military vehicle, and eliminates the recurring logistics cost and safety footprint of pressurized nitrogen cylinder management in a field environment.

Exhibit 2 | AM Feedstock Logistics Reform Roadmap: From Unit Improvisation to Doctrinal Standard

Action	Policy Authority	Timeline	Responsible Organization
Assign National Stock Numbers to standard military-specification AM feedstock at each tier: PETG, ASA, CFRP-nylon, CSAM aluminum powder, nitrogen gas cylinders for cold spray; publish through DLA AM Implementation Plan	DoDI 5000.93 (DLA AM raw material management mandate); DLA AM Implementation Plan	0-12 months	DLA / USD(A&S) / DoD ManTech
Establish unit basic loads for AM feedstock as a line item in modified tables of organization and equipment for all units authorized AM equipment; specify load by echelon (Tier 1: 10 kg polymer; Tier 2: 5 kg CFRP + 10 kg polymer; Tier 3: 20 kg polymer + 20 kg metal powder + nitrogen)	Army MTOE process; DoDI 5000.93; TRADOC Force Design	6-18 months	Army G4 / PEO Aviation / TRADOC
Publish an Army Techniques Publication or Technical Manual establishing environmental storage standards, packaging requirements, and field quality acceptance procedures for each AM feedstock category; integrate into 15E MOS training curriculum	DoDI 5000.93; ASTM WK83145 (on publication); ARL materials research findings	12-24 months	Army G4 / DEVCOM ARL / TRADOC / Ordnance School
Establish DLA forward pre-positioned feedstock stocks in PREPO sets associated with AM-equipped units; baseline on Class IX PREPO model; update annually based on consumption data from deployed units	DoDI 5000.93; DLA Strategic Plan; FY2026 NDAA Section 865 (contested logistics demonstration)	18-36 months	DLA / Army G4 / FORSCOM
Identify and pre-qualify commercial feedstock suppliers in each major operational theater (Pacific, Europe, Middle East) as Host Nation Support feedstock sources; establish quality acceptance test procedures for commercial-source feedstock	DoDI 5000.93; SOFA/HNS framework; FY2026 NDAA supply chain resilience provisions	12-24 months	Army G4 / OPLAN logistics annexes / theater ASCCs

Action	Policy Authority	Timeline	Responsible Organization
Establish domestic and allied-nation feedstock procurement preference policy for PETG, ASA, and CFRP filament; publish preferred supplier list for NDAA-compliant polymer feedstock, parallel to Blue UAS framework	FY2026 NDAA supply chain illumination; DFARS sourcing restrictions; DoD DIB Industrial Strategy	0-18 months	USD(A&S) / DLA / DoD ManTech / America Makes
Evaluate portable membrane nitrogen generator systems as authorized equipment for Tier 3 cold spray AM nodes, replacing pressurized cylinder logistics; complete engineering evaluation and publish results	FY2026 NDAA Section 871 (contested logistics demonstration); Army Futures Command OT&A	12-24 months	Army Futures Command / PEO GCSS-Army
Apply DARPA SURGE performance-based qualification framework to AM parts produced using tactically-sourced feedstock; establish acceptance criteria for parts printed from commercial-sourced materials	FY2026 NDAA Section 220A; DARPA SURGE (2024-2028); DoDI 5000.93	24-48 months (tied to SURGE program output)	DARPA / DEVCOM ARL / PEO Aviation / USD(R&E)

5. The NDAA Feedstock Gap: Hardware Is Addressed, Materials Are Not

FY2026 NDAA Section 849 prohibits DoD from procuring AM machines manufactured by or networked through entities domiciled in China, Russia, Iran, or North Korea, effective one year after enactment in December 2025. The restriction applies to the procurement of a covered additive manufacturing machine, defined as a system of integrated hardware and software, including material deposition and associated post-processing steps. It does not apply to feedstock materials. A Tier 1 AM node equipped with a NDAA-compliant printer loaded with Chinese-manufactured PETG filament satisfies the Section 849 hardware requirement but sustains Chinese feedstock supply chain exposure.

The NDAA's Section 842 prohibition on procuring batteries from foreign entities of concern, and Section 846's prohibition on molybdenum, gallium, and germanium from non-allied nations, establish the legislative precedent for materials-level supply chain restrictions. Congress has demonstrated willingness to restrict specific materials when the supply chain security case is made. The case for polymer filament sourcing restrictions is less acute than for semiconductor materials because the global polymer industry is more geographically distributed. However, in a deliberate denial scenario, adversary export restrictions on nylon precursor resins or specialty polyamide compounds could constrain CFRP filament production in ways analogous to the gallium embargo's effect on GaN semiconductor supply.

The DoD's Defense Industrial Base Fund, expanded by FY2026 NDAA Section 867 to include power sources and advanced manufacturing, provides the investment authority for supporting domestic AM feedstock production

capacity. A targeted investment in domestic PETG, ASA, and CFRP filament production infrastructure, analogous to the solid rocket motor production capacity investments made under Defense Production Act Title III authority, would provide the supply chain resilience the tactical AM enterprise requires and does not currently have.

6. Operational Implications: What Allied and Observed Models Indicate About Feedstock at Scale

Ukraine's distributed FPV drone production ecosystem, which scaled from approximately 20,000 FPV drones per month in January 2024 to 200,000 per month by December 2024, provides the most operationally complete reference model for feedstock management at scale in a contested environment. Ukrainian drone producers overwhelmingly use commercial polymer filament: PLA, PETG, and ABS in standard 1.75mm format, sourced through commercial supply chains that operated continuously throughout the conflict despite Russian targeting of Ukrainian infrastructure. The three-month design cycle documented in open-source reporting on Ukrainian drone development, in which drones produced at one point share almost no design features with those produced twelve months earlier, imposes a specific feedstock requirement: the material must be compatible with rapidly changing design files without re-qualification, which commodity polymers satisfy because their material properties are consistent across suppliers and well-characterized in standard FFF printers.

The British Army's Bull Storm exercise in Kenya in May 2025 demonstrated the minimum feedstock logistics footprint for field FPV production: one truck carrying printers, generators, commercial components, and feedstock sufficient to sustain operations. The French Army's 17th Artillery Group containerized 3D mobile autonomous factory, producing 60 to 80 FPV drones per day in operation, is powered by a generator and includes filament stock sufficient for sustained production inside a containerized facility. Neither model specifies the storage standard applied to that filament stock in field conditions. This gap between operational precedent and doctrinal standard is the specific problem this paper addresses.

The Hawkeye Platoon of the U.S. Army's 173rd Airborne Brigade demonstrated drone production during the Agile Spirit 2025 exercise in Georgia, combining printed parts and commercial components to produce airframes adapted to specific missions in a matter of hours at below $500 per unit. The AMUG 2025 panel discussion on forward deployment AM noted that the real complexity in tactical AM lies in managing end-to-end workflows across diverse technologies and security domains; the 3YOURMIND representative cautioned against reducing the challenge to the common image of FDM printing in a Humvee. The feedstock management dimension, which adds environmental storage, resupply logistics, quality verification, and supply chain provenance requirements to an already complex forward deployment problem, reinforces that caution. The printer in the Humvee is the visible end of a logistics chain whose requirements must be specified before the capability can scale.

7. Conclusion: The Material Problem Behind the Manufacturing Ambition

The Secretary of the Army's April 2025 directive to extend additive manufacturing to operational units by 2026 represents an institutional commitment to a capability that is operationally proven, technically mature, and strategically valuable. The Hawkeye Platoon has demonstrated it. The French 17th Artillery Group produces it daily at volume. Ukraine has built an industrial ecosystem around it at scale. The capability exists, and the argument for extending it is well established. Secretary Driscoll's observation that a UH-60 Black Hawk screen control knob that costs $47,000 from the original equipment manufacturer can be printed for $60 is the cost argument that makes the case.

What does not yet exist is the logistics doctrine to sustain that capability in a tactical environment. A printer fields with a finite quantity of filament. When that filament is consumed, the capability pauses unless the resupply system delivers more. If the filament is stored incorrectly and degrades before consumption, the capability produces defective parts without visible indication. If the filament supply chain is disrupted by adversary action or export restriction, the capability stops regardless of how many NDAA-compliant printers are in the field.

The feedstock at Tier 1 costs approximately $0.15 per gram in PETG. Printing the $47,000 knob consumes perhaps $0.50 in material. If the unit's filament stock has absorbed moisture over three days in a tropical environment in an unsealed commercial spool, the printed knob may exhibit layer delamination under vibration load after a short service period. The $0.50 material investment becomes a maintenance incident and the $47,000 OEM part is ordered anyway, plus a maintenance action.

Feedstock doctrine is the difference between AM as a sustainable organic maintenance capability and AM as a pilot that performs in controlled conditions and degrades when the first field environment challenges it. The eight reform actions in this paper address that difference through actions grounded entirely in existing policy authority: DoDI 5000.93, the FY2026 NDAA's expanded DIB Fund authority, ASTM standardization efforts already underway, and the DoD supply chain illumination framework. The printer is the hardware. The feedstock is the fuel. The doctrine must address both with equal rigor.

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