AMPOWER INSIGHTS

Additive Manufacturing **in Defense**

How AM Addresses the Critical Challenges of Modern Military Forces Worldwide

INSIGHTS GAINED

- How armed forces use AM
- Identifying the most effective strategies
- How the AM sector leverages defense growth
- Overview of deployable AM units

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INSIGHTS GAINED

How armed forces use AM for rapid response, mission flexibility, and readiness.

Identifying the most effective strategies to integrate AM into defense logistics and missions.

How the AM sector leverages defense growth to drive innovation and scale.

Overview of deployable AM units available for field and expeditionary use.

MANAGEMENT SUMMARY

Since 2022, Europe's security landscape has been reshaped by the war in Ukraine, exposing critical weaknesses in traditional defense procurement and supply chains. Ammunition shortages, obsolete parts, and single source dependencies have limited operational readiness across NATO. While European nations are injecting unprecedented funding into defense, with Germany's €100 billion special fund being a prime example, industrial retooling and cross border harmonization remain slow.

At the same time, the conflict has revealed that battlefield success increasingly depends on rapid adaptation, printing, modifying, and deploying components within days. Additive Manufacturing (AM) has emerged as a key enabler of such agility. The U.S. Department of Defense demonstrates how structured AM strategies, digital part frameworks, and distributed production networks can transform sustainment logistics.

Europe must follow suit by aligning national initiatives, NATO standards, and industry innovation. The success of Ukraine's DRUKARMY, a distributed volunteer network producing millions of 3D printed parts, shows the power of decentralized, digitally coordinated production for resilience.

For European defense, AM offers immediate impact in low volume spares, field repairs, and prototyping, while paving the way toward full scale integration into defense logistics. Through a phased approach of Enablement, Harmonization, and Deployment, AM can evolve from experimentation to an operational backbone, ensuring readiness, autonomy, and strategic independence in a new era of defense modernization.

Download this paper at www.ampower.eu/insights

ABOUT AMPOWER

AMPOWER is the leading strategy consultancy and thought leader in the field of industrial Additive Manufacturing. The company advises investors, start-ups as well as suppliers and users of 3D printing technology in strategic decisions, due diligence investigations and provides unique access to market intelligence. On operational level, AMPOWER supports the introduction of Additive Manufacturing through targeted training programs, support in qualification of internal and external machine capacity and technology benchmark studies. The company was founded in 2017 and is based in Hamburg, Germany, operating worldwide.

ABOUT AM ACADEMY

AM Academy offers independent Additive Manufacturing education services and is powered by AMPOWER. The company collaborates with end users to support them in the definition and implementation of their AM strategy using online learning courses and live trainings. The AM Academy is supplier-agnostic and encompasses all Additive Manufacturing technologies, emphasizing hands-on, industry-relevant content. The company was founded in 2024 and is based in Hamburg.

Content

Introduction

Europe's armed forces at a turning point

The war in Ukraine has forced European militaries to rethink their strategies, shifting from peace-time structures to forces prepared to defend their territory against current and potential adversaries.

Since 2022, Europe's security environment has changed fundamentally. The on going conflict in Ukraine has not only driven a major and continuing rise in European military spending, but it has revealed how quickly peacetime procurement rhythms break down under sustained demand: ammunition consumption outpaced industrial surge capacity, ageing platforms ran into parts obsolescence, and single-source suppliers became operational choking points. These are not abstract procurement problems but immediate operational frictions that leave aircraft, armored vehicles and ships temporarily unavailable and constrain training and deployment.

Germany's response illustrates the dilemma: very large, politically supported infusions of cash, a €100 billion special fund, create the resources to modernize and replenish stocks, but converting spending into fielded capability requires extensive industrial planning, re-tooling and harmonized procurement across borders, none of which can be fixed quickly and by budgets alone. Other European states have also increased budgets, yet persistent fragmentation in standards and certification keeps cross-border resilience and surge in defense production below the level NATO planners say is required.

At the same time, the tactics and tools proven in Ukraine force a re-thinking of what militaries must be able to do quickly. Uncrewed aerial systems, low-cost FPV and loitering munitions, pervasive ISR and the resulting "transparent" battlefield have privileged units that can iterate sensor packages, mounts, counter-UAS measures and improvised effectors rapidly. Ukraine's battlefield improvisation underlines that operational advantage often depends less on one big procurement win and more on the ability to adapt hardware and supplies in days and weeks, to print a bracket, reconfigure a sensor housing, or fabricate a custom tooling part close to the point of need.

This is where Additive Manufacturing (AM) becomes relevant in practice and the European defense players, and military units must quickly adapt and learn not only from Ukraine but also from the US. The US Department of Defense (DoD) has shown a clear path for making AM operationally useful at scale: publish an enterprise strategy, build implementing guidance, establish a digital-thread approach for secure part files, run joint qualification efforts and create distributed, accredited AM nodes linking industry, depots and forward repair hubs. The Department of Defense's AM strategy and the Defense Logistics Agency's implementation plan are explicit about these building blocks, policy, trusted data, qualification frameworks and a phased, use-case driven rollout. Those elements are as important as the printers themselves for turning on-demand manufacturing into a reliable logistics capability.

There are clear near-term payoffs: producing low-volume legacy spares that are no longer commercially stocked; enabling depot and forward repairs for housings, brackets and non-flight-critical components; and accelerating prototype cycles for mission-specific fittings and sensors. But adoption is conditional since flight-critical and high-temperature structural parts still demand stringent material qualification, process control and traceability before AM can replace conventional production at scale.

Europe must quickly adapt and embrace the potential that lies in Additive Manufacturing. A key to success lies in aligning national initiatives, European structures and harmonization with NATO frameworks while maintaining high innovation speed. The AM industry and many promising startups are already at the forefront of this movement.

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Global Defense Adoption of Additive Manufacturing: From NATO to China

Defense organizations worldwide are scaling investments in AM. The U.S. leads with large-scale budgets and service-branch programs, Europe and allies are building dual-use innovation strategies, and China is rapidly advancing AM across aerospace, missiles, and field logistics. Together, these initiatives illustrate a global race to integrate AM into the future of defense.

Additive Manufacturing has moved from experimentation to a strategic capability in defense. The U.S. Department of Defense maintains the world's largest known AM budget, with over $3 billion across 16 programs focusing on spare parts, advanced materials, and digital supply chains. Within the services, the U.S. Air Force's Rapid Sustainment Office alone committed nearly $1 billion to accelerate sustainment and prototyping with 3D printing.

In Europe, the European Defense Fund dedicates part of its €7.3 billion budget (2021–2027) to disruptive technologies, including AM for joint capability projects. The UK Ministry of Defense has embedded AM into its Defense Advanced Manufacturing Strategy, targeting over £100 million in savings by localizing spare parts production. Beyond NATO, Australia's Additive Manufacturing CRC, backed with AUD $58 million, supports dual-use defense and industry applications.

Meanwhile, China has emerged as the most ambitious rival. Guided by Made in China 2025 and the 14th Five-Year Plan, Chinese defense contractors and PLA branches are deploying AM across multiple domains. AVIC and AECC integrate 3D-printed parts into next-generation fighters and engines, while CASC and CASIC apply AM to rockets, satellites, and hypersonic weapons. The PLA also tests field-deployable printers and drones for rapid repair, underscoring logistics resilience.

Together, these efforts signal that AM is no longer peripheral but central to military modernization, with both NATO allies and China racing to leverage its advantages for readiness, agility, and strategic independence.

U.S. Department of Defense – Additive Manufacturing Programs (USA)
FY2026 budget request allocates USD3,300M to AM projects (83% increase over FY2025). Covers 16 programs, with ~USD2,300M in the Industrial Base Analysis and Sustainment (IBAS) program. Goal: embed AM in weapons procurement, sustainment, and resilient logistics.

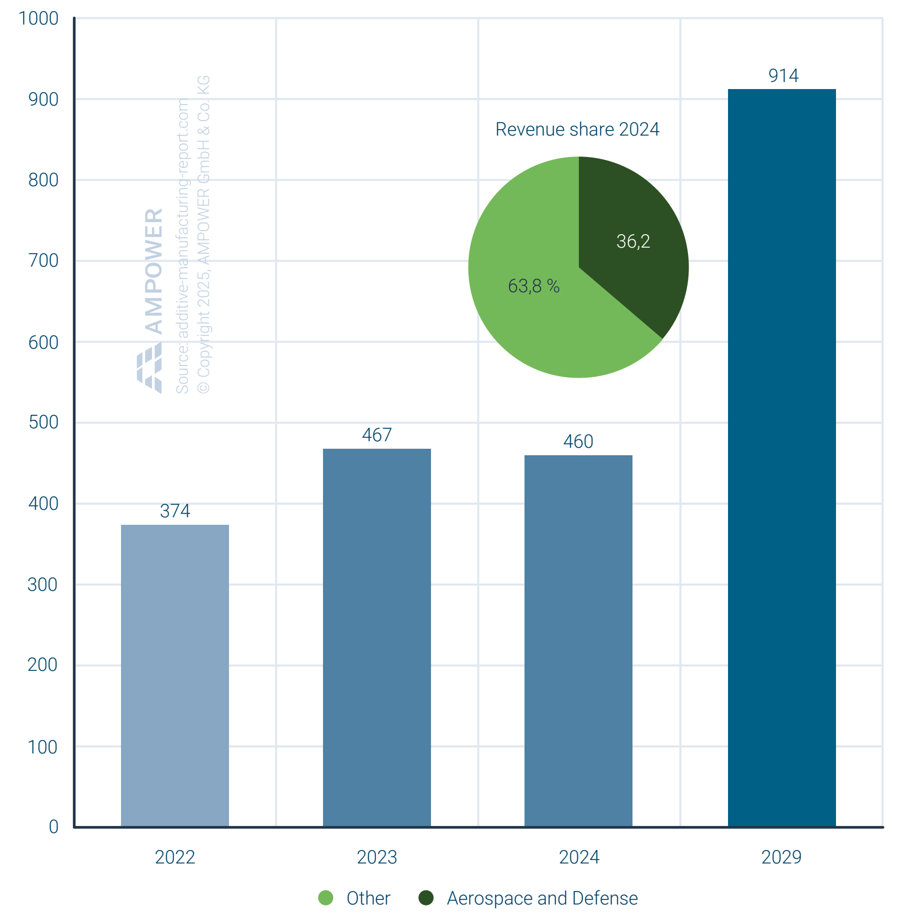
U.S. Air Force – Rapid Sustainment Office (USA)
In 2024 awarded a potential USD975M (5-year base, 4-year option) contract to 67 vendors for prototyping, including AM. Funds on-site 3D printing for parts and repair aids in the field. Objective: reduce downtime via on-demand spares and battle-damage repair.

European Defense Fund – Collaborative AM R&D (EU)
EDF budget of EUR7,300M (2021–2027). ~4–8% dedicated to disruptive tech including AM. Supports multi-country projects on AM materials, processes, and certification to strengthen the defense industrial base.

UK Ministry of Defense – Advanced Manufacturing Strategy (UK)
First Defense Advanced Manufacturing Strategy published in 2025. Report estimated that printing 15% of spares could save GBP110M over 15 years. Focus: incentivize AM adoption, update policies, and create digital inventories.

Australia – Additive Manufacturing CRC (Australia)
Government committed AUD58M within a AUD 271M seven-year package. Public–private consortium (101 partners incl. defense and aerospace) to develop AM technologies, materials, and workforce skills for defense supply chains.

Metal equipment revenue in Aerospace and Defense 2022 to 2024 and forecast 2029 [EUR million]



Applications

Operational Value of AM across OEM Applications

Defense primes increasingly leverage Additive Manufacturing to develop mission-ready components that outperform legacy designs in agility, weight, and lead time. With AM, suppliers meet the evolving operational demands of high-performance, low-volume parts that are difficult or impossible to manufacture conventionally.

Multiple defense companies are adopting Additive Manufacturing to gain tactical and logistical advantages across a growing range of component categories. Defense suppliers prioritize design agility, weight reduction, functional integration, and streamlined supply chains: areas where AM offers immediate strategic impact.

The defense sector is characterized by low-to-mid production volumes, stringent qualification cycles, and specialized part geometries, making AM an ideal fit. Polymer-based parts have already seen wide deployment in non-critical applications such as UAV housings, soldier gear components, and covers. Meanwhile, metal applications like propulsion parts, munition guidance sections, or hypersonic thermal barriers are gaining traction as process maturity improves and production cost decrease.

We analysed a wide range of AM applications used by Defense companies and mapped them based on:

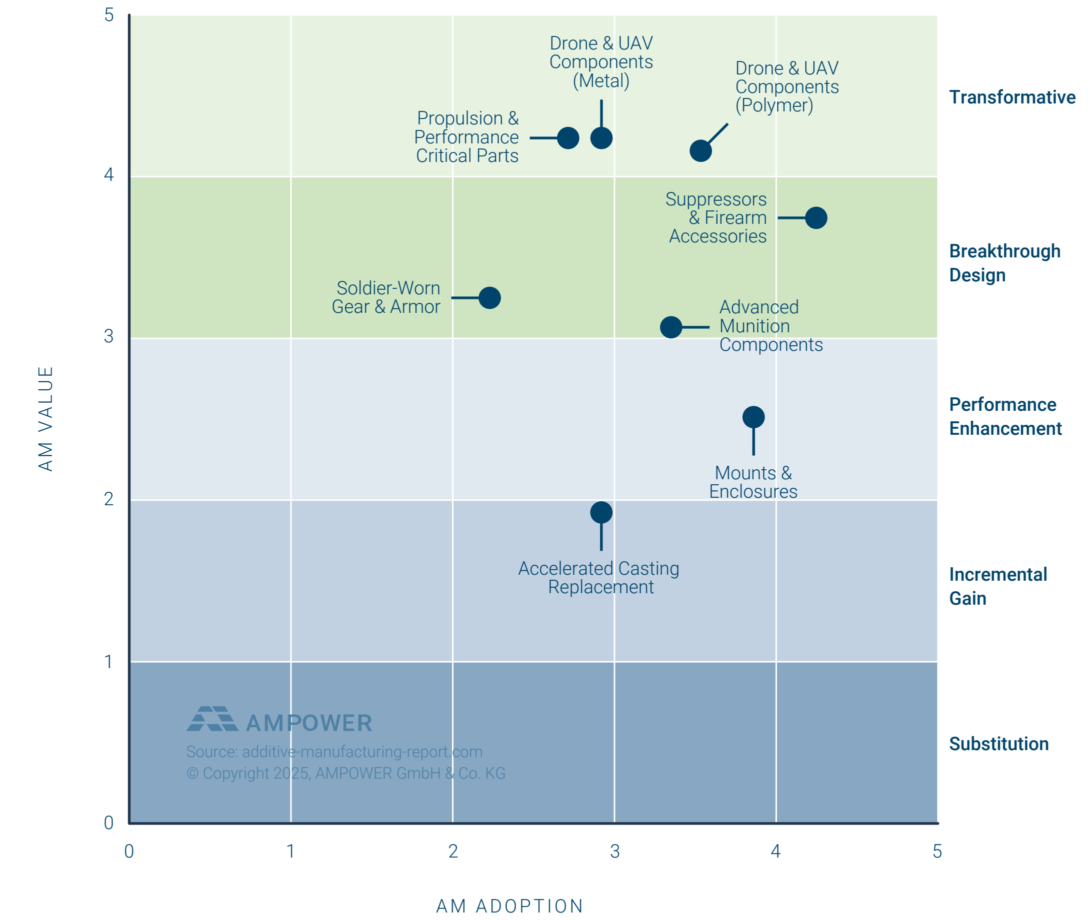
AM Value: the performance gains, supply chain impact and cost effectiveness made possible by AM

AM Adoption: the current maturity level and industry-wide implementation of AM in each category.

Each category reflects how AM is transforming defense procurement: from rapid prototyping and field repair to full-scale deployment of production-grade hardware.

BeeTa relay systems extending FPV drone range — 3D printed mobile and ground-based units ensure stable control and video links in challenging terrain. Image courtesy: DRUKARMY

Adoption and Value of AM in Military OEM Applications



AM Value

Indicates the strategic benefit derived from AM, including weight reduction, part consolidation, supply chain resilience, performance breakthroughs and cost effectiveness.

AM Adoption

Reflects the implementation maturity across OEM programs, considering technical readiness, part qualification, supply chain integration, and repeatable production deployment.

Category	Material	Description	AM Value
Mounts & Enclosures	Metal & Polymer	Housings, brackets, and covers for avionics, optics, and electronics	Optimized for performance, weight, and survivability.
Drone & UAV Components	Metal & Polymer	Frames, enclosures and mission-specific components	Lightweight, low-cost and fast production, fast customization
Suppressors & Firearm Accessories	Metal	Suppressors, muzzle brakes, flash hiders	Reduced weight, improved performance, fewer parts
Propulsion & Performance Parts	Metal	Engines, nozzles and thrust components for UAVs and hypersonics	Heat resistance, integration, efficient geometry
Advanced Munition & Weaponry	Metal	Guidance sections, aerodynamic and performance-critical features	Faster, cheaper production; integrated functionality
Soldier-Worn Gear & Armor	Metal & Polymer	Helmet parts, armour plates, wearable gear frames	Lighter load, modular customization, scalable production
Accelerated Casting Replacement	Metal	Large marine and industrial parts as casting substitutes	Faster lead times, local production, repair capability

How Military Units Deploy AM for Tactical Sustainment

Additive Manufacturing is becoming a critical enabler for military units tasked with maintaining equipment availability in the field. Deployable AM solutions allow for rapid repair, spare part production, and system sustainment directly at the point of need, cutting lead times, reducing logistics dependency, and maximizing operational readiness.

Military units are increasingly turning to Additive Manufacturing as a strategic asset for maintaining critical equipment near the front lines. In contested logistic environments or expeditionary operations, part availability becomes a limiting factor for mission success. AM enables units to bypass traditional supply chains by fabricating parts on-site, directly where and when they are needed. The primary use case is the rapid production of spare and replacement parts to sustain vehicles, weapons systems, and other mission-critical assets. Whether it is replacing a broken bracket on a tactical vehicle or fabricating a field antenna mount, AM empowers troops to restore functionality within hours instead of weeks.

Polymer AM, especially Material Extrusion printers, are the frontline workhorses due to their low system cost, compact size, and plug-and-play usability. They require minimal training, operate on limited power, and need little to no post-processing, making them ideal for decentralized, mobile deployment or even crowd-sourced production within the defense network.

Metal AM capabilities remain more logistically demanding but are rapidly advancing. Technologies such as Directed Energy Deposition (DED) and Cold Spray are widely recognized for in-field repair of damaged or worn parts, including vehicle hulls, gun barrels, and rotor shafts. Laser Powder Bed Fusion (L-PBF) offers high-precision builds, but typically requires more controlled environments and post-processing infrastructure. To overcome these hurdles, integrated, ruggedized AM container units, such as those offered by Fieldmade and others, are enabling full-spectrum AM in mobile, self-sufficient form. These modular units house polymer, metal, or composite AM systems coupled with post-processing, power supply, and air filtration, creating a turnkey "factory in a box" that can deploy anywhere logistics demands.

Key AM technologies in deployable solutions & suitability per domain

Technology	Material Type	Key Use Cases	Air	Land	Sea
Material Extrusion	Metal & Polymer	Covers, brackets, housings, mounts	High	High	Medium
Powder Bed Fusion	Metal & Polymer	Engine parts (metal), UAV brackets, structural components	High	Medium	Medium
Directed Energy Deposition	Metal	Repair of shafts, rotors, weapon parts	Medium	High	High
Cold Spray	Metal	Surface restoration, corrosion repair, coatings	Low	High	High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Case Study

COURTESY OF DRUKARMY

Decentralized frontline production with AM: The DRUKARMY model

DRUKARMY demonstrates how a decentralised, volunteer-driven AM network can provide critical battlefield agility by turning urgent requests from frontline operators into delivered parts within hours: bypassing conventional, slow logistics chains.

Military logistics have long been recognized as the backbone of operational success. Yet, in high-intensity and distributed conflicts, traditional supply systems, which are designed for predictability and scale, quickly reveal their limits. The ongoing war in Ukraine has highlighted this challenge in stark terms: even small, seemingly simple components can become unavailable for weeks once centralized depots, transport routes, or suppliers are disrupted. In such an environment, agility and local problem-solving become as decisive as firepower.

Amid these constraints, AM has emerged as a crucial enabler of resilience. By allowing parts to be fabricated directly where they are needed, AM eliminates dependencies on vulnerable supply chains and enables frontline units to maintain readiness despite disruption. What once required industrial tooling, procurement approvals, and long transport cycles can now be achieved with a laptop and a desktop printer.

The Ukrainian volunteer initiative DRUKARMY has taken this principle to its logical conclusion. Founded shortly after the full-scale invasion, it has grown into a distributed manufacturing network that combines thousands of individual printers, engineers, and designers into a functional, self-coordinating ecosystem. Its purpose is straightforward but transformative: to supply the front lines with urgently needed components: quickly, affordably, and at scale.

Today, the network includes over 8,000 printers, operated by more than 3,000 volunteers and makers across Ukraine and allied European countries. Collectively, they have produced more than 18 million parts with a combined weight of over 700 tonnes of printed polymer. These range from drone mounts, cable protectors, and rifle accessories to medical tools and training aids. Each item contributes in small but vital ways to the endurance and efficiency of military and rescue units.

DRUKARMY's success lies not only in the number of printers or parts produced, but in the speed and resilience of its model. Requests that would take months to fulfil through formal procurement are now resolved within hours. In a conflict defined by constant adaptation, this responsiveness has become a strategic advantage.

18.000.000+
Parts delivered to the front

700.000+
Kg printed plastic

100.000+
Completed orders

3.000+
Active makers and volunteers

8.000+
Printers in the network

Scope mounts for heavy machine guns used by mobile air-defense teams against Shahed-type UAVs. Affordable, rugged, scalable—equip many crews fast.

ZIR — FPV detector / video receiver: intercepts enemy FPV video; usable handheld, vehicle-mounted, or in shelters. Early warning and actionable awareness.

QinFlow Warrior training mock-up — full-scale 3D-printed blood-warmer. Enables setup/connection/transfusion drills, building muscle memory without risking the original; for medics, paramedics and training centers.

Mortar Mine Extractor — a non-lethal safety tool that enables safe removal of a stuck round from the mortar tube. Essential for frontline mortar crews.

Varios produced parts as part of the DRUKARMY initiative. Courtesy for all images: DRUKARMY

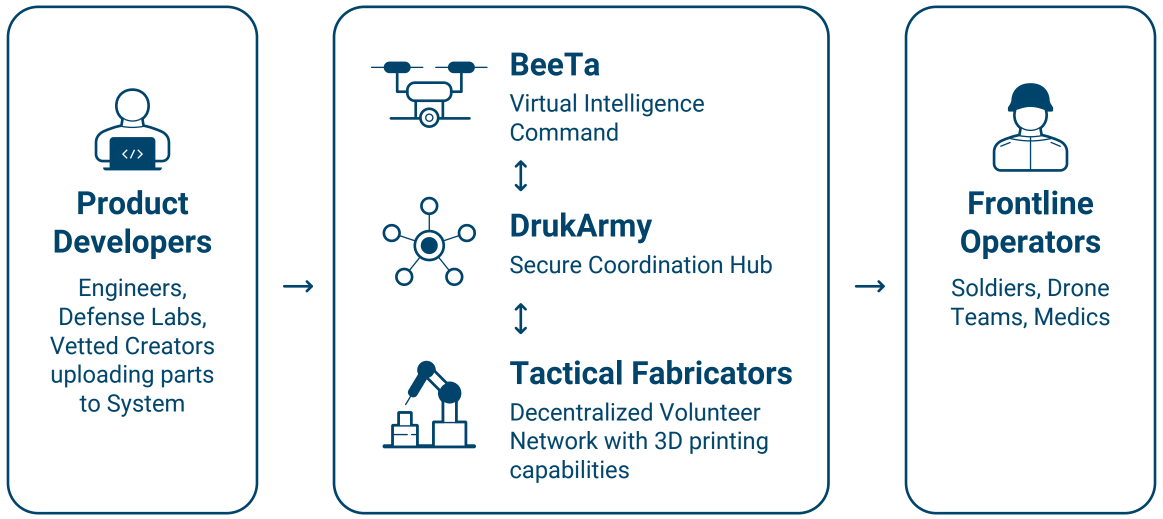
At its core, DRUKARMY operates through a digital coordination platform known as BeeTa, which connects three roles in a simple but powerful loop: frontline operators, who identify immediate needs; product developers, who design or adapt 3D models; and tactical fabricators, who print and dispatch the required parts. Requests from the front are logged, categorized, and automatically matched with available production capacity within the network. Fabricators then print the parts on standard Material Extrusion systems, perform basic quality checks, and hand them over to delivery volunteers or military couriers. The turnaround from request to delivery is often measured in hours rather than weeks.

This decentralized coordination model enables a continuous flow between demand, design, and delivery. Frontline units report needs through secure digital channels, often specifying basic dimensions or operational constraints. Product developers validate or refine the 3D model, drawing from a growing catalogue of approved designs. BeeTa then allocates print jobs based on proximity, printer capability, and material availability, ensuring that each request is fulfilled by the most suitable node in the network. The vast majority of production relies on polymer AM, especially Material Extrusion (ME) processes using PETG, PLA, or ABS. These materials strike a balance between mechanical strength and ease of printing, while remaining cost-effective and accessible. Most printers in use are consumer-grade systems such as Bambu Lab, Prusa, or Creality models, chosen for their reliability, plug-and-play usability, and compact footprint. Despite their simplicity, these systems have proven capable of producing durable, mission-relevant parts that can withstand field conditions.

DRUKARMY complements this distributed capacity with lightweight but effective quality assurance mechanisms. Every printed item undergoes a visual inspection, is photographed, and receives a unique batch identifier. For safety-critical components, print files and parameters are verified centrally, and production is routed through accredited hubs with enhanced QA standards. This ensures consistency and traceability without undermining the network's speed and flexibility.

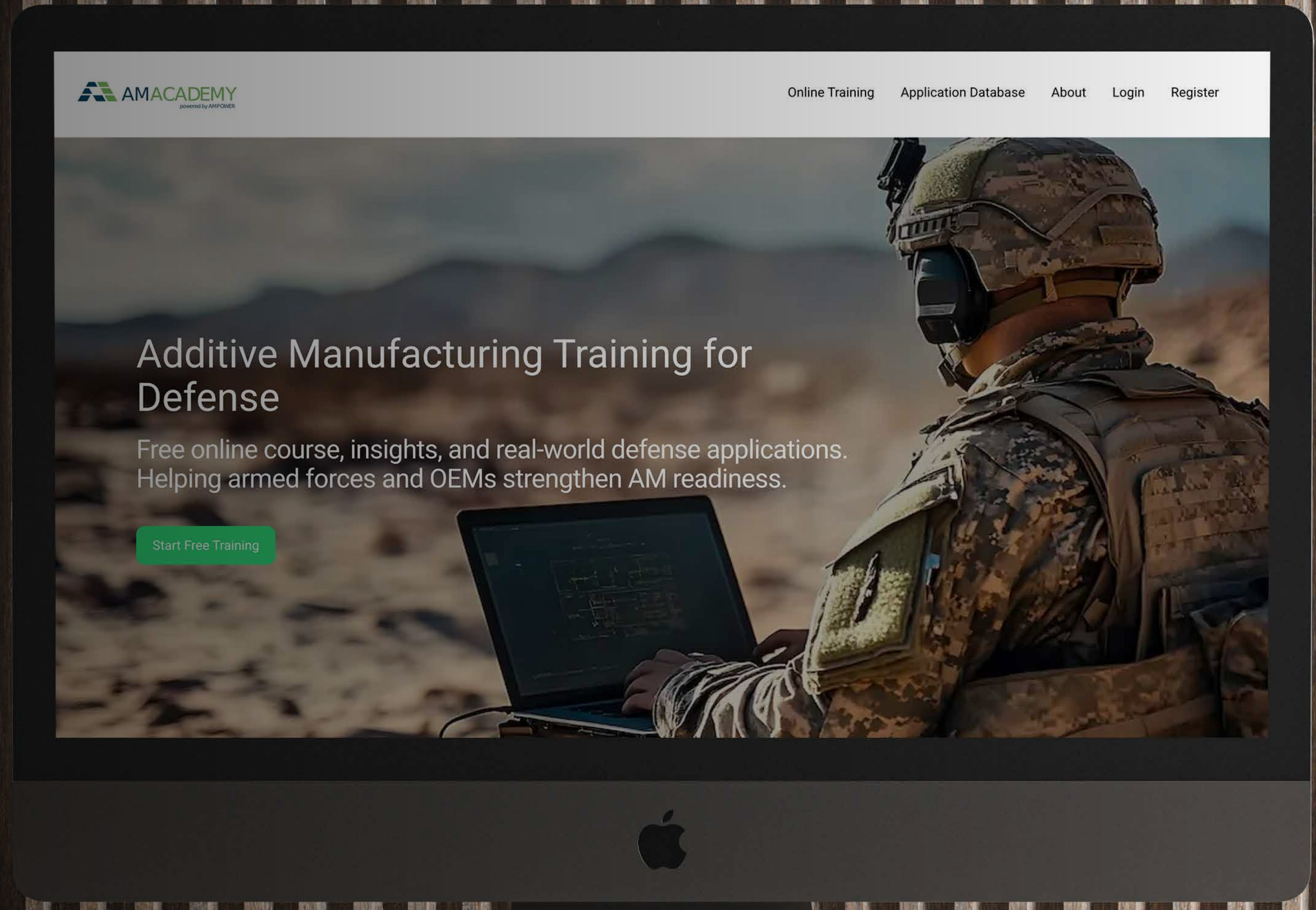
Beyond its immediate tactical value, the DRUKARMY model represents a scalable blueprint for resilient, civilian-supported defense logistics. It demonstrates how AM, when combined with trusted digital infrastructure and volunteer engagement, can transform logistics from a centralized bottleneck into a distributed, adaptive capability. For future European defense planning, it provides not only a technical example, but a human one: how networks of citizens, engineers, and soldiers can together sustain national resilience under pressure.

The DRUKARMY Ecosystem



Browse a growing list of applications for Defense companies and military units in our online data-base.

WWW.ADDITIVE-MANUFACTURING-DEFENSE.COM/APPLICATION-DATABASE



Strategies

Military implementation strategy

Military units can learn from industries like Oil and Gas and Rail when developing an implementation strategy for AM. Success depends on how well flexibility and speed of AM are aligned with the lag created by necessary standardization and the knowledge gap.

The integration of AM across European and NATO forces requires a structured approach that balances innovation at the tactical level with standardization at the strategic level. This transformation can be achieved through three progressive phases: Enablement, Harmonization, and Deployment.

In the Enablement phase, small military units are empowered to adopt AM by developing point-of-need applications, fostering collaboration with technology providers, and building regional Centers of Excellence to share industrial capabilities. Early use cases are identified, documented, and incentivized through regional competitions, establishing a foundation for widespread adoption.

The Harmonization phase aligns these regional initiatives under a unified European and NATO framework. Standardized qualification procedures, secure data protocols, and NATO-approved training ensure interoperability and consistent performance across allied forces. This phase also strengthens Europe's AM supply chain, qualifying systems, materials, and services to meet defense-grade requirements.

Finally, the Deployment phase operationalizes AM across all defense regions. Harmonized standards and best practices are rolled out through logistics, maintenance, and production networks. Trained personnel and certified systems are deployed at strategic and tactical levels, supported by continuous feedback loops and performance monitoring. AM thus evolves from isolated projects into an interoperable, mission-ready capability embedded within Europe's defense infrastructure.

Adoption Under Combat Conditions

Unlike European defense forces, Ukraine has had no time to develop a long-term AM strategy or follow a phased integration model. Facing immediate battlefield challenges, Ukrainian forces have adopted a hands-on and adaptive approach, incorporating AM directly into operations while standards and formal qualification processes emerge only later.

This "deploy first, standardize later" model has proven that even without comprehensive frameworks, AM can deliver rapid, mission-critical solutions. The urgency of war has driven innovation, enabling frontline units and local engineers to design, produce, and deploy components on demand. While not sustainable as a long-term structure, Ukraine's experience demonstrates that flexibility, improvisation, and direct application can accelerate the acceptance of new technologies and highlight their strategic value under real combat conditions.

Peacetime Strategy

1 Enablement

- Empower small units to employ AM for maintenance, repair, and mission-specific production.
- Identify point-of-need applications where AM delivers clear tactical or logistical value.
- Establish regional reporting and knowledge exchange channels to collect, evaluate, and disseminate successful use cases.
- Foster collaboration between military units and AM solution providers to accelerate practical implementation.
- Set up a regional AM Center of Excellence to coordinate training, share industrial print capacity, and ensure access to advanced systems.
- Incentivize innovation and use case development through regional AM competitions and recognition programs.

2 Harmonization

- Align regional AM activities at the European level to enable coordinated capability development, shared data standards, and unified certification pathways.
- Develop a unified European and NATO AM framework that defines qualification, data security, and interoperability standards for systems and materials.
- Create NATO-approved AM training and certification standards to ensure personnel across all member states operate with consistent technical competence and procedural understanding.
- Qualify the European AM supply chain — encompassing systems, materials, services, and software — to guarantee compliance with military-grade requirements and NATO interoperability.
- Establish cross-border collaboration mechanisms between defense agencies, industry, and academia to maintain alignment and accelerate technological maturity.

3 Deployment

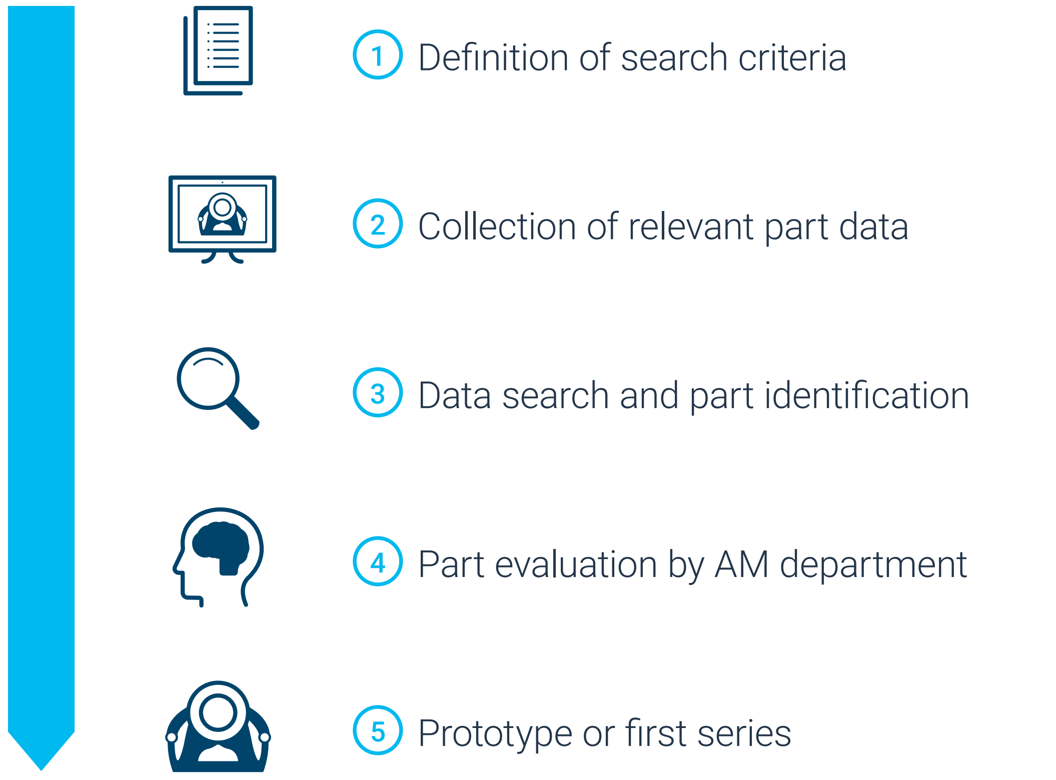
- Roll out NATO and European harmonized standards and best practices across all regional defense organizations to ensure consistency, interoperability, and compliance.
- Integrate AM into existing defense logistics and maintenance structures to enable distributed manufacturing and reduce dependency on traditional supply chains.
- Deploy qualified AM systems and trained personnel at strategic and tactical levels to guarantee readiness and resilience across all theaters of operation.
- Monitor, evaluate, and optimize AM performance through continuous feedback loops, operational data collection, and cross-border knowledge sharing.
- Maintain interoperability through ongoing alignment reviews ensuring that evolving technologies and procedures remain compatible across NATO members.
- Institutionalize AM governance and lifecycle management within defense procurement and capability development processes to sustain long-term integration.

Top-down vs. Bottom-up

Two approaches are known for identifying potential parts for Additive Manufacturing. The bottom-up method leads to a wider range of applications and higher potentials. The top-down method may yield fast results assuming reliable data is available and meaningful search criteria can be identified and combined. For military units, a bottom-up strategy is expected to yield more promising results.

In field spare parts and repair are one of the biggest potentials for Additive Manufacturing in Defense units. Leveraging this potential is only possible by creating awareness of the technology capabilities on a broad scale in maintenance units. Using a brute force approach of simultaneous training, enablement and incentivization by creating a competitive environment between units, has proven to be successful in the field.

Top-down



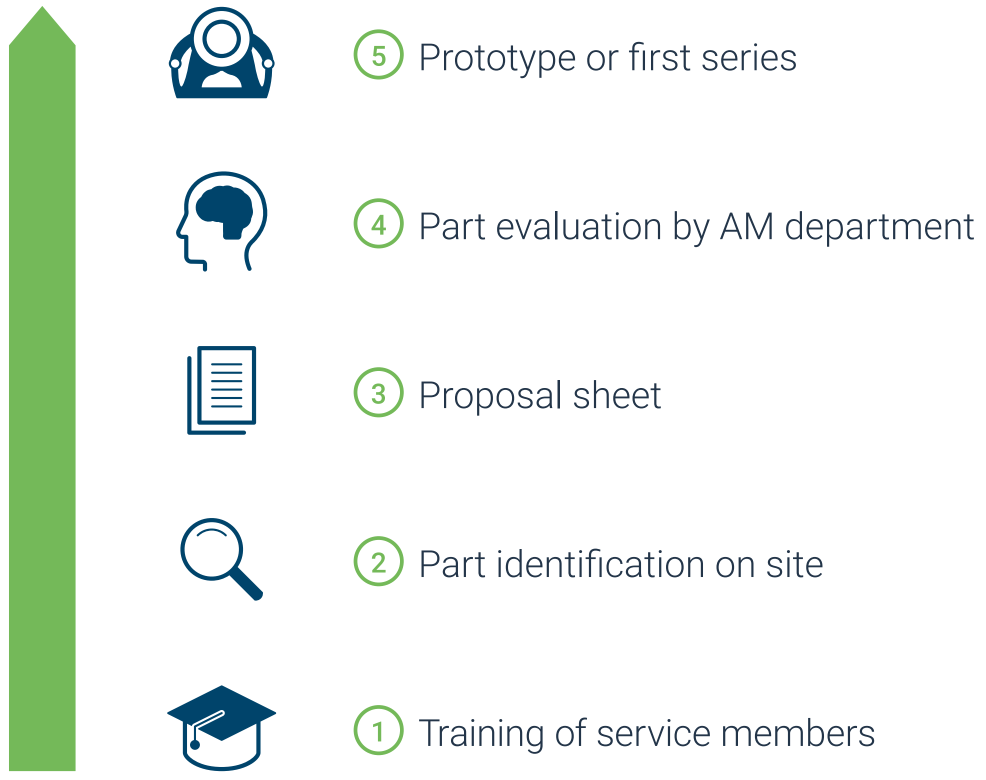
Advantages

- Fast screening of large amounts of parts
- Objective assessment
- Scalability

Disadvantages

- Difficult collection of relevant data
  - Varying sources (SAP, CAD, drawing)
  - No CAD data available
  - Different formats (digital, analog)
- Extremely large amount of information
- Software or search tool necessary
- Soldiers and maintenance crews are not involved, possible resentment

Bottom-up



Advantages

- Involvement of service members and maintenance personnel reduces change risks
- Problems at point of need are solved which increases acceptance
- Identification of relevant parts from field experience
- Easy collection of relevant data
- Higher chance to optimize parts instead of just replacing them

Disadvantages

- Time-consuming and expensive training of service members
- Possibly subjective assessment, dependent on degree of know-how
- Screening limited to smaller amounts of parts, less scaling
- No standards incorporated in early stage

Technologies & Suppliers

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Technology optimized for frontline deployment

Producing spare parts and mission-critical components in austere environments places unique demands on AM systems. Solutions must be robust, transportable, and easy to operate under conditions far removed from industrial production halls.

Producing parts in extreme environments on the frontline sets strict requirements for any AM system. Robustness, ease of use, and transportability are essential to ensure machines operate reliably in harsh and unpredictable conditions. A growing number of suppliers have addressed these needs with specially designed or adapted solutions. Broadly, two main approaches can be distinguished:

Container solutions integrate printers and their periphery into standard or custom container units. These provide mobility, environmental protection, and often allow flexible setups hosting one or multiple machines.

Ruggedized printers, on the other hand, are existing systems that have been reinforced and optimized for field use. Modifications focus on durability, shock resistance, and simplified operation to meet frontline requirements.

Together, these solutions enable on-demand production directly in deployed scenarios, supporting operational readiness with greater autonomy and flexibility. Across this spectrum, systems can be categorized into containerized production units, modular systems, and ruggedized field printers. Containerized units offer the highest production capacity but require setup and utilities, making them ideal for base-level operations. Modular systems combine good performance with improved transportability and faster deployment. Ruggedized printers represent the most flexible category, allowing compact and rapid part manufacturing or repair directly in the field.

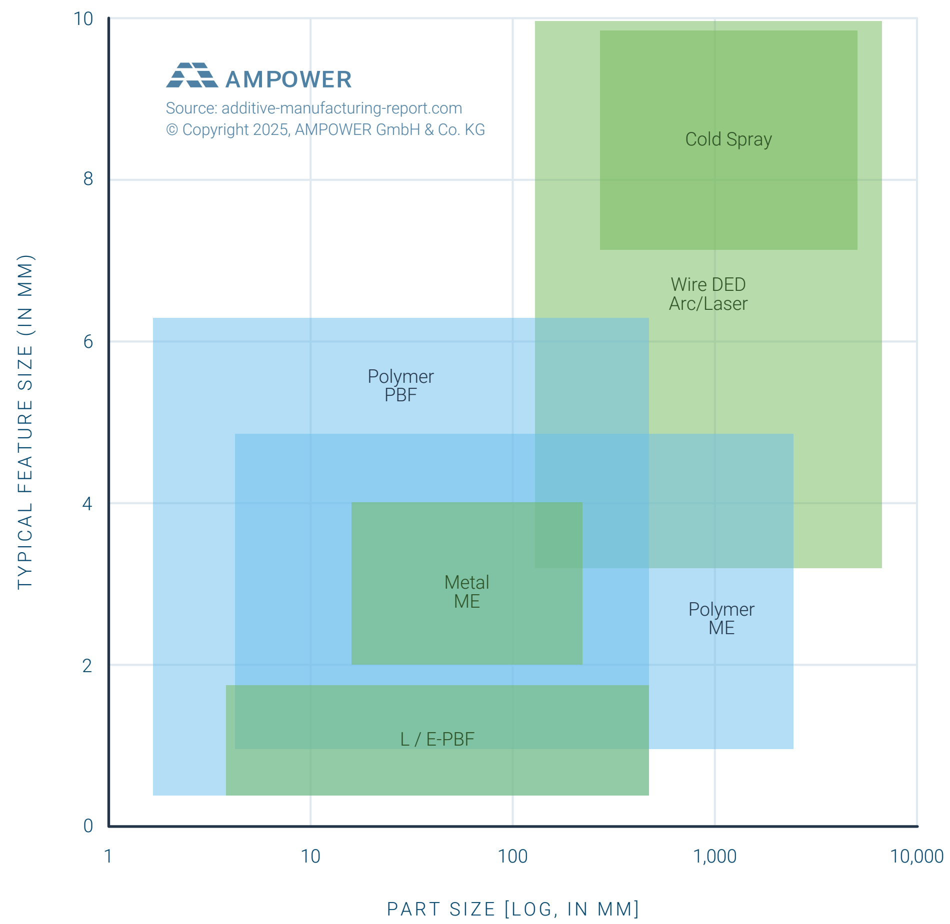
Deployment spectrum of field-ready AM systems

Containerized production units
High-capacity, large-scale systems requiring setup and utilities.

Modular systems
Transportable solutions combining performance with easier setup.

Ruggedized field printers
Compact, low-infrastructure printers for frontline manufacturing.

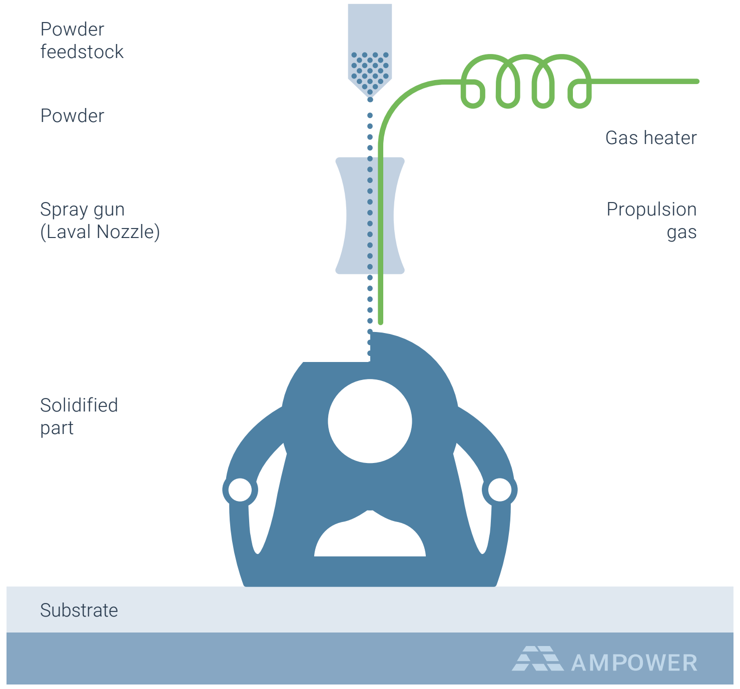
Typical range of part size vs. feature size for metal and polymer technologies



Suitable AM technologies for field-operations

Cold Spray

Cold Spray is a solid-state additive process in which metallic powders are accelerated to supersonic speeds and bonded through high-velocity impact, without melting the material, making it ideal for rapid repair and coating applications in harsh environments.

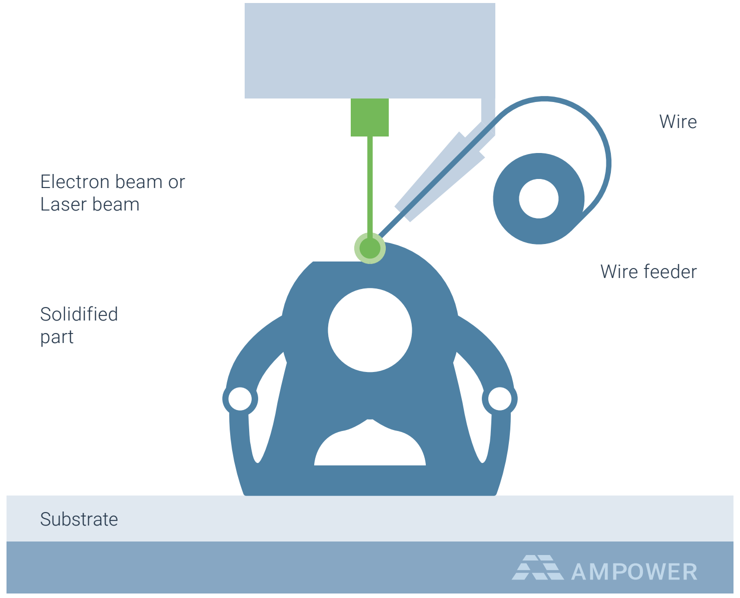


Key Technology Parameters

Energy source: Electrical heating
Feedstock: Metal or polymer filament or pellets
Key use cases: Covers, mounts, enclosures
Mobility: High
Ease of use: Medium
Post processing: Medium

Wire Laser Directed Energy Deposition

Wire Laser Directed Energy Deposition (DED) is a laser-based AM process that feeds metal wire into a localized molten pool created by a laser beam. The technology enables efficient and fast metal builds for both part production and repair.

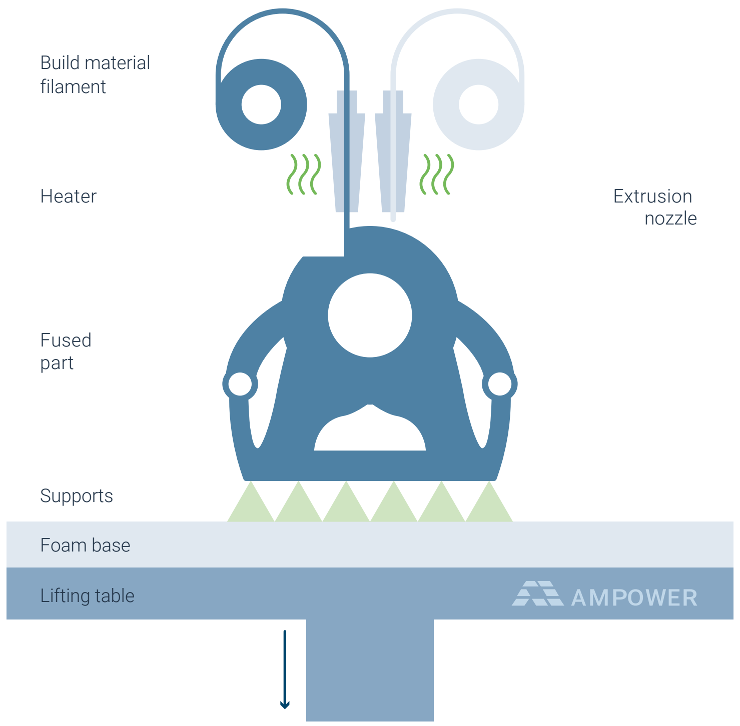


Key Technology Parameters

Energy source: Laser or infrared heating
Feedstock: Metal or polymer powder
Key use cases: Functional parts, housings, tooling inserts
Mobility: Low
Ease of use: Low-Medium
Post processing: High

Material Extrusion

Material Extrusion is one of the most versatile AM processes, extruding molten material through a nozzle to build parts layer by layer. It is widely used due to its simplicity, scalability, and ability to process a broad range of materials.

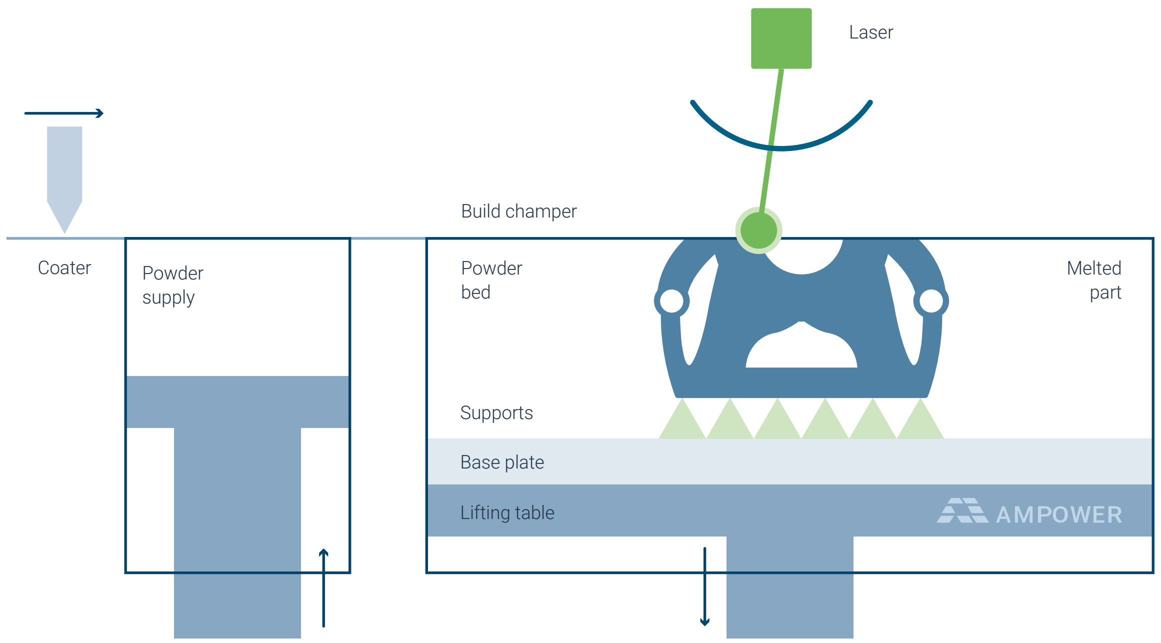


Key Technology Parameters

Energy source: Electrical heating
Feedstock: Metal or polymer filament or pellets
Key use cases: Covers, mounts, enclosures
Mobility: High
Ease of use: High
Post processing: Low

Powder Bed Fusion

Powder Bed Fusion (PBF) builds parts by selectively fusing powder layers using thermal energy. Laser PBF melts metal or polymer powders with a laser, while Thermal PBF (e.g. MJF) uses infrared energy and fusing agents. The process offers high precision, material efficiency, and excellent part quality.

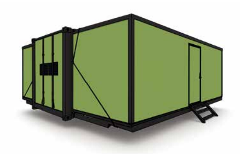


Key Technology Parameters

Energy source: Laser or infrared heating
Feedstock: Metal or polymer powder
Key use cases: Functional parts, housings, tooling inserts
Mobility: Low
Ease of use: Medium
Post processing: High

Commercial Additive Manufacturing field solutions

Container Solutions

Company	Solution	Technology	Material Group	Container Footprint	Build Volume
 Additec	HYBRiD-X	DED (Wire Laser)	Metal	3.0 m × 2.4 m × 2.9 m (approx. 10-foot container)	760 x 460 x 460 mm
 Fieldmade	NOMAD Series	L-PBF (Metal or Polymer), Material Extrusion	Polymer and Metal	20-foot container	Depends on technology
 Rapidflight	Mobile Production System	Material Extrusion	Polymer	20-foot container	Depends on technology
 Speed3D	Expeditionary Manufacturing Unit (EMU)	Cold Spray	Metal	2x 20-foot container	Ø 900 × 700 mm
 Firestorm Labs	xCell Mobile Factory	PBF (MJF)	Polymer	2x 20-foot containers	380 x 284 x 380 mm
 Rheninmetall	Mobile Smart Factory (MSF)	DED (Wire Arc), Material Extrusion	Polymer and Metal	20-foot container	DED: Ø 500 x 450 mm ME: 300 x 200 x 270 mm
 Rheinmetall	Smart Lab Light (SLL)	Material Extrusion	Polymer	Trailer platform	300 x 200 x 270 mm (depending on model)

Ruggedized Printers

Company	Solution	Technology	Material Group	Footprint	Build Volume
 Bigrep	IPSO 105	Material Extrusion (High Temp)	Polymer	1.3 x 1.1 x 1.7 m	400 x 600 x 440 mm
 Markforged	X7 Field Edition	Material Extrusion (composites)	Polymer	0.6 x 0.5 x 0.9 m	330 × 270 × 200 mm
 Geofrabrica	xAM	Material Extrusion	Metal and Polymer	-	355 × 305 × 254 mm
 Craitor	FieldFab	Material Extrusion (High Temp)	Polymer	0.6 × 0.7 × 1 m	280 × 280 × 280 mm

Container Solutions

COURTESY OF SPEE3D

Fast facts on SPEE3D EMU

Solution: Expeditionary Manufacturing Unit (EMU)
Technology: Cold Spray
Material Group: Metal
Solution Type: Container

SPEE3D supplies mobile manufacturing equipment, such as the EMU, that enables soldiers and sailors to design, 3D print, post-process and test metal parts on site and within hours.

Technology Overview

Technology: Cold Spray
Max build size: Ø 900 x 700 mm (40 kg) for XSPEE3D printer
Footprint: 2x 20-ft. ISO container (6.2 × 2.6 × 2.6 m)
Throughput: up to 100g/min

Deployment Concept

Two 20-ft ISO containers:
- XSPEE3D printer
- SPEE3Dcell post-processing (HT furnace, CNC mill, tooling, testing).

Designed for rapid deployment in austere environments;
Operational within 1 hour using standard 3-phase power.

Materials & Feedstock

Feedstock: Powder
Validated materials: Al 6061, 316 SS, Cu, Bronze-variants (others in development)
Platform: Open, users can develop unique alloys.

Key Capabilities

"Replacement of mid-size metal parts, metal coatings or rapid repair"
- Non-melting, gas- and laser-free process for safer operation.
- TwinSPEE3D software provides full print simulation and anomaly detection.
- Enables redesign and remanufacture of obsolete parts.

Adoption & References

Adopted by defense organisations in US, UK, Ukraine, Japan, and Australia.
- Bradshaw Field Training Exercise (AUS Army)
- Project Convergence / ITX-423 (US Army & Marines)
- NAVSEA REPTX / Trident Warrior / RIMPAC (US Navy)
- European Defence Agency AM Village (British Army)
- Validated for hull, mechanical, and electrical repairs during RIMPAC 2024.

Limitations & Notes

- Material range: Primarily Al-, Cu- (e.g. Bronze) and Fe-Alloys (e.g. Stainless Steel)
- Operating temp: 4 – 35 °C (tested from −18 °C to tropical humidity)
- Certification: CE marked

RHEINMETALL

Fast facts on Rheinmetall SLL

Solution: Smart Lab Light
Technology: Material Extrusion
Material Group: Polymer
Solution Type: Transporter / trailer-based

The Smart Lab Light (SLL) is a deployable 3D printing solution specially tailored to the requirements of military customers in the field of mobile and rapidly deployable polymer printing.

Technology Overview

Technology: Material Extrusion (multi-printer-setup)
Max build size: 300 x 200 x 270 mm per printer
Footprint: Up to 10 printers; modular configuration on trailer platform
Throughput: Depending on printer model, nozzle and print parameters

Deployment Concept

- Trailer-based, mobile system designed for rapid deployment in the field.
- Fully modular design enables integration of AM and post-process.
- Power supply configurable (external or onboard)
- Setup and operation require minimal training.

Materials & Feedstock

Feedstock: Filament
Materials: Standard and fibre-reinforced polymers
- Open-material approach with no vendor lock-in.
- Rheinmetall provides recommended material lists for field use.

Key Capabilities

- Rapid, field-deployable polymer printing
- Configurable printer count and layout
- Simple logistics and maintenance
- Supported by Rheinmetall IRIS digital suite

Adoption & References

Developed by Rheinmetall Landsysteme GmbH.
Tested internally at Rheinmetall

Limitations & Notes

Limited total build volume due to trailer size
Operates under standard ambient conditions (no climate control required)
No certification constraints for non-critical polymer parts

RHEINMETALL

Fast facts on Rheinmetall MSF

Solution: Mobile Smart Factory (MSF)
Technology: DED / Material Extrusion
Material Group: Metal & Polymer
Solution Type: Container

A modular, container-based factory that can be used for battle damage repair, repair or new production, and which maps the entire process chain, from data preparation to ready-to-install spare parts, regardless of location.

Technology Overview

Technology: Wire Arc-DED (Hybrid: DED + Milling), Material Extrusion (ME)
Max build size: Ø 500 × 450 mm (DED) | 300 × 200 × 270 mm (ME)
Footprint: 20-ft. ISO container (6.2 × 2.6 × 2.6 m)
Throughput: up to 600 cm³/h (DED) | 330 cm³/h (ME)

Deployment Concept

- Container-based modular factory designed for remote or austere environments.
- Requires 63 A / 32 A power; optional diesel generator enables off-grid use.
- Setup and relocation < 1 hour; minimal calibration.
- Operable by 1–2 trained personnel; multiple trainings (including XR) available.

Materials & Feedstock

DED: Weldable wire (steel, Al, Ti, Cu – Ti needs special enclosure)
Material Extrusion: Standard and fibre-reinforced filaments.
- Open-material approach with no vendor lock-in.

Key Capabilities

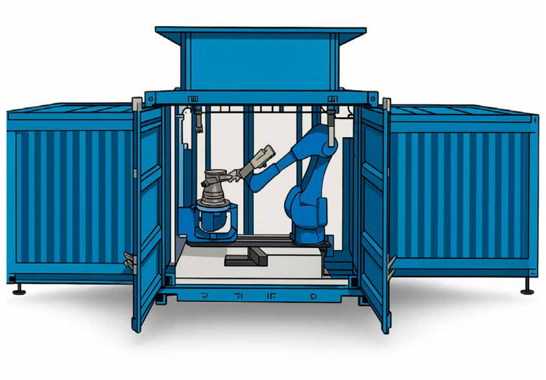
- Integrated additive + subtractive manufacturing in one platform
- Full workflow from data preparation, printing to installation
- Enables repair & new production
- Compact logistics footprint; standardized consumables
- Supported by Rheinmetall IRIS digital suite

Adoption & References

MSF has been tested and operated in multiple field trials;
customer details confidential.
Developed and manufactured by Rheinmetall Landsysteme GmbH.

Limitations & Notes

Requires trained operator
Automation under development
Certified parts limited to temporary replacement use
Modular setup allows user-specific configuration



Fast facts on Additec

Solution: HYBRiD-X
Technology: DED / Liquid Metal Jetting (LMJ)
Material Group: Metal
Solution Type: Container

HYBRiD-X – Containerized Hybrid Additive Manufacturing Platform for Forward-Deployed, Mission-Critical Metal Production.

Technology Overview

Technology: Hybdid DED (Laser DED + CNC) / Liquid Metal Jetting (LMJ)
Max build size: 760 × 460 × 460 mm
Footprint: 3.0 m × 2.4 m × 2.9 m (approx. 10 ft container)
Throughput: up to 4 kg/h (DED) | 0.11 kg/h (LMJ)

Deployment Concept

Containerized, modular, and ruggedized manufacturing platform for remote or forward operations.
Power: 480 V (3-phase)
Setup: Rapid installation (< 1 hour) with minimal calibration
Operator skills: Standard CNC / AM technician level

Materials & Feedstock

Materials: Metals (defense-grade alloys)
Feedstock: Wire

Key Capabilities

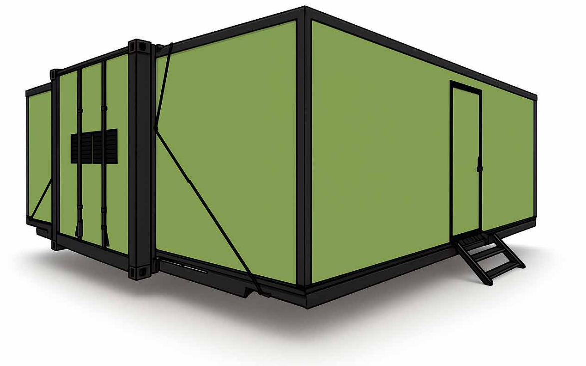
Speed & Productivity: High deposition rates for rapid component fabrication.
Integrated Hybrid Platform: Combines additive + subtractive + multi-material processes in a single container.

Adoption & References

U.S. Navy: LMJ printer deployed aboard USS Essex, first metal 3D printer installed at sea.
Follow-on Trials: USS San Diego (LPD-22), aluminium component production.
Upcoming Program: Fleetwerx Program for Advanced Manufacturing for Contested Logistics, led by the Naval Postgraduate School (NPS).

Limitations & Notes

Certification: MIL-STD qualification in progress.
Material development: 4140 steel feedstock optimisation for ballistic applications ongoing.



Fast facts on Fieldmade

Solution: NOMAD® Series
Technology: L-PBF (Metal or Polymer), Material Extrusion
Material Group: Metal & Polymer
Solution Type: Container

A self-sustained, climate-controlled shelter, housing advanced additive manufacturing technology, tailored to your needs.

Technology Overview

Technology: L-PBF (Metal or Polymer), Material Extrusion
Max build size: Depends on systems
Footprint: From ruggedized cases to larger double-expanding cases
Throughput: Depending on printer model and print parameters

Deployment Concept

- Spans from ruggedized carry-on cases to double-expanding 20-ft container units.
- Modular design enabling integration of multiple AM technologies and post-processing tools.
- Operates on standard industrial power or field generators.
- Rapid setup and operation by trained personnel, supported by tailored training and mixed-reality assistance.

Materials & Feedstock

Feedstock: Powder and Filament
Metals: 316L, IN625/718, AlSi10Mg, M300, etc.
Polymer: PA12, PA11 (SLS); PA-CCF, PP-CF, TPC, etc.

Key Capabilities

- Rugged, modular design for operation in remote and austere environments.
- Printing capability established within one hour of deployment.
- Flexible choice of technology (L-PBF metal, polymer, or ME) and materials.
- Climate-controlled system ensuring stable operation in all conditions.

Adoption & References

- 9,400+ parts produced in civilian deployments
- Validated by multiple NATO partners
- Exercises: TRJE18, CL19, FLOTEX19, CR22, PC22, Nordic Response 2024
- U.S. Army XTECH award (NOMAD® LW & NOMAD® 03)

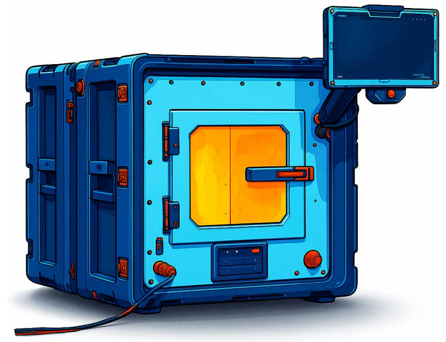
Limitations & Notes

Operating conditions: Built for Nordic climates, fully weather-resilient

Rugged Printers

COURTESY OF MARKFORGED

CRAITOR



Fast facts on Craitor

Solution: FieldFab Expeditionary 3D Printer
Technology: Material Extrusion
Material Group: Filament
Solution Type: Rugged Printer

FieldFab Expeditionary 3D Printer" FieldFab enables the production of mission-critical parts and attritable systems at the tactical edge.

Technology Overview

Technology: Material Extrusion (ME)
Max build size: 280 x 280 x 280 mm
Footprint: 99 x 61 x 66 cm
Throughput: Dependent on material/nozzle setup

Deployment Concept

- Ruggedized, two-man portable system operable without shelters or containers.
- FieldFab deploys from packed to printing in under 5 minutes
- Runs on standard 80–264 V AC power
- Functions reliably in extreme environments (−40 °C to +50 °C, 0–100 % humidity)
- Minimal training using Craitor's SecureTDP workflow.

Materials & Feedstock

Feedstock: Filament
Supported materials: base materials (e.g. PLA, PETG, PET-CF), high-performance materials (e.g. Nylon-CF, TPU, ULTEM 9085)
Open polymer platform (no license needed)
Heated chamber (80 °C), bed (200 °C), and nozzle (500 °C)

Key Capabilities

- Produces high-strength polymer parts for sustainment
- Deploy-to-print in under 5 minutes.
- Works in any environment with any operator skill level.
- Uniquely able to actively print parts on the move during ground vehicle transportation.
- Non-camera in-situ system with 21 sensors generates a PDF quality report for each printed part

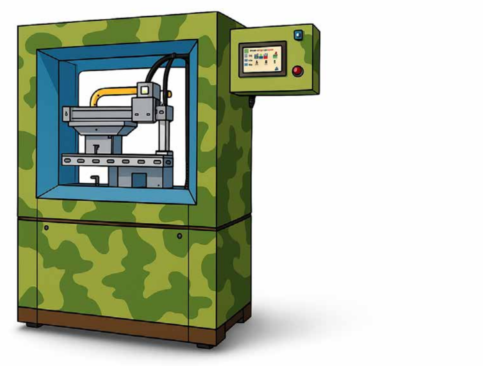
Adoption & References

- Adopted by U.S. Army, Navy, Air Force, and allied forces.
- Used in over 28 field exercises for expeditionary sustainment and repair.
- Example: T-REX 25-2 (Indiana Army National Guard): first-ever in-flight 3D printing aboard a UH-60 Black Hawk, successfully producing UAS parts mid-flight.

Limitations & Notes

No current in-situ camera-based error detection (planned for future).
Certified MIL-STD-810H, AS9100D / ISO 9001 compliant.

bigrep



Fast facts on BigRep

Solution: BigRep One, BigRep VIIO 250, BigRep ALTRA 280
Technology: Material Extrusion
Material Group: Polymer
Solution Type: Rugged Printer

On-demand manufacturing of mission-ready and large-format parts directly in the field

Technology Overview

Technology: Material Extrusion
Build volume:
- BigRep ONE – 1 × 1 × 1 m (non-heated chamber)
- BigRep VIIO 250 – 1 × 0.5 × 0.5 m (50 °C chamber)
- BigRep ALTRA 280 – 0.5 × 0.7 × 0.8 m (150 °C chamber)

Footprint: ~1.1 × 1.2 m (IPSO 105) – 1.95 × 2.5 m (PRO)
Throughput: Up to 200 g/h

Deployment Concept

- Delivered fully assembled for quality and alignment
- Shipped in wooden crates or flight cases for mobile use
- Power: 208–240 V or 400–480 V (32 A, 3P)
- Stable temperature and dust-free setup recommended

Materials & Feedstock

Feedstock: Filament
Open polymer platform (no license needed)
All base and performance polymers can be used

Key Capabilities

- Industrial large-format printing up to 1m build envelope
- End-to-end solution including machine, software, materials and service

Adoption & References

- In active use at military organizations
- Example: collaboration with SFM Technology and Leonardo Helicopters

Limitations & Notes

Certification for FFF applications still developing (focus currently on metal AM)
Large parts require environmental control for dimensional stability
Final certification depends on customer-specific process setup

Markforged

Fast facts on Markforged

Solution: X7 Field Edition
Technology: Material Extrusion + Carbon Fiber
Material Group: Polymer
Solution Type: Rugged Printer

A rugged, field-deployable continuous carbon-fiber composite 3D printer designed for point-of-need production in disconnected, austere environments

Technology Overview

Technology: Material Extrusion + Carbon Fiber
Max build size: 330 × 270 × 200 mm
Footprint: 584 × 483 × 914 mm (48 kg)
Throughput: Depends on geometry; up to 250 µm layers and "Turbo Print" modes

Deployment Concept

- Fully rugged Pelican AL3232 transport case with integrated foam & locks
- Entire kit (printer + tools + spares + materials) ≈ 85 kg
- Setup to print < 3 min; designed for disconnected field ops
- Operates on mains, generator, UPS, or solar
- Offline-capable with STIG-compliant OS and version-controlled part library

Materials & Feedstock

Feedstock: filament spools (polymer + dedicated fiber)
Base polymers: Onyx, Onyx FR (UL94 V-0), Onyx ESD, Nylon White, P-PLA, S-TPU
Continuous fibers: Carbon Fiber, Kevlar, Fiberglass, HSHT Fiberglass
Environment: drybox included for moisture-controlled storage

Key Capabilities

- CFR composites with strength comparable to 6061-T6 aluminum (~40 % lighter)
- Low SWaP-E: ~150 W power draw, compact 36" case footprint
- Secure, offline workflows for DoD use

Adoption & References

- US Navy: AFLOAT program: installed on USS New Hampshire (SSN-778)
- US Marine Corps: TACFAB / XFAB programs of record
- US Army / USAF: Cannon AFB (27 SOW) field tooling applications
- Partners: NAVSEA, NUWC, NSWC, NASA, Blue Origin, SpaceX

Limitations & Notes

- Build size limited to 330 × 270 × 200 mm
- No blanket airworthiness; certification per use case
- Requires covered setup in rain/dust; dry filament essential
- MIL-STD-810 ruggedization tested for DoD POR

AM Academy Plattform

Bridging the AM Knowledge Gap in Defense

While AM technologies and suppliers are ready to deliver cost savings and enhanced capabilities, a fundamental knowledge gap within the defense sector remains a critical barrier. Education and awareness are essential to ensure that allocated budgets translate into real operational advantages.

Governments have demonstrated a strong commitment and announced plans to invest in Additive Manufacturing in order to enhance products and increase equipment uptime. The challenge is not related to the maturity of the technology itself. The real barrier lies in perception. Many decision makers continue to view Additive Manufacturing through an outdated lens, which limits its adoption in large-scale defense programs.

This lack of understanding prevents procurement teams and military stakeholders from fully leveraging the operational benefits of Additive Manufacturing. While civilian industries and leading defense contractors already use it to achieve lighter components, faster lead times, and reduced costs, many armed forces remain far from exploiting its full potential.

Closing this knowledge gap is not optional but essential. Comprehensive training programs and structured knowledge transfer between industry experts and defense procurement teams are required. Only with this foundation can the defense sector unlock the strategic advantages of Additive Manufacturing, achieve sustained cost savings, improve readiness, and build greater resilience for future operations.

Build up mission-critical skills

Tailored AM online learning course for defense professionals

- Understand the fundamentals of key AM technologies relevant to defense
- Explore material options and their performance in harsh environments
- Gain insight into real-world defense applications and case studies
- Recognize the strategic potential and limitations of AM in defense operations

ONLINE LEARNING AVAILABLE AT:

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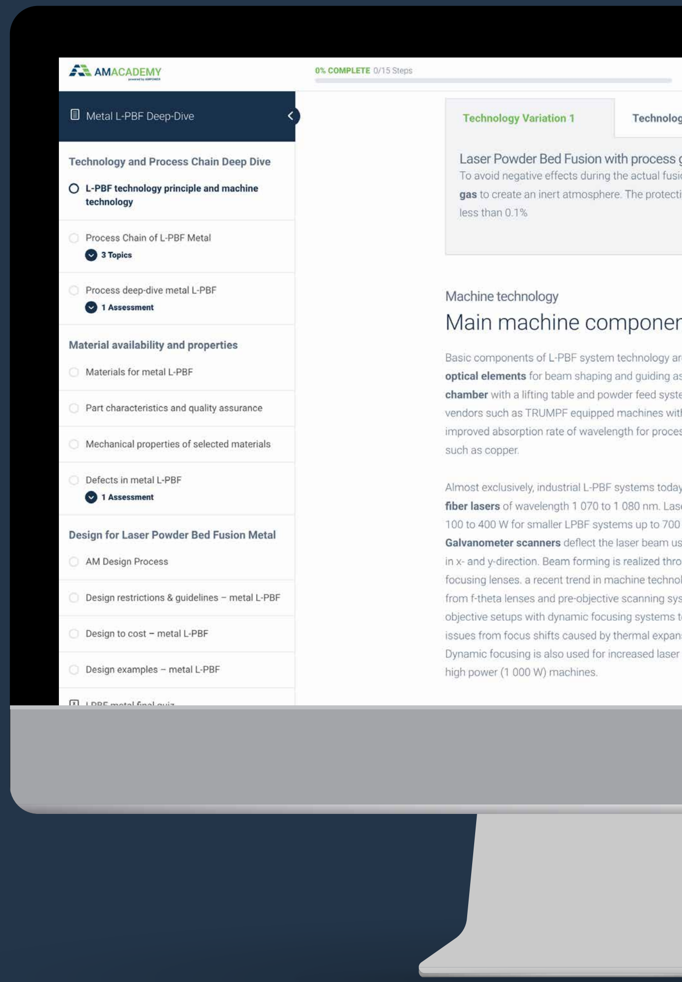


About the authors

Benjamin Haller

MANAGING DIRECTOR AT AM ACADEMY

Benjamin Haller specializes in guiding companies to successfully implement and benefit from Additive Manufacturing. He has worked with end users across several industries to support them in setting their AM strategy and implementing AM. With experience in a wide range of metal and polymer AM technologies, Benjamin has trained countless professionals, including designers, managers, and others, empowering them to innovate and grow.

Matthias Schmidt-Lehr

MANAGING PARTNER AT AMPOWER

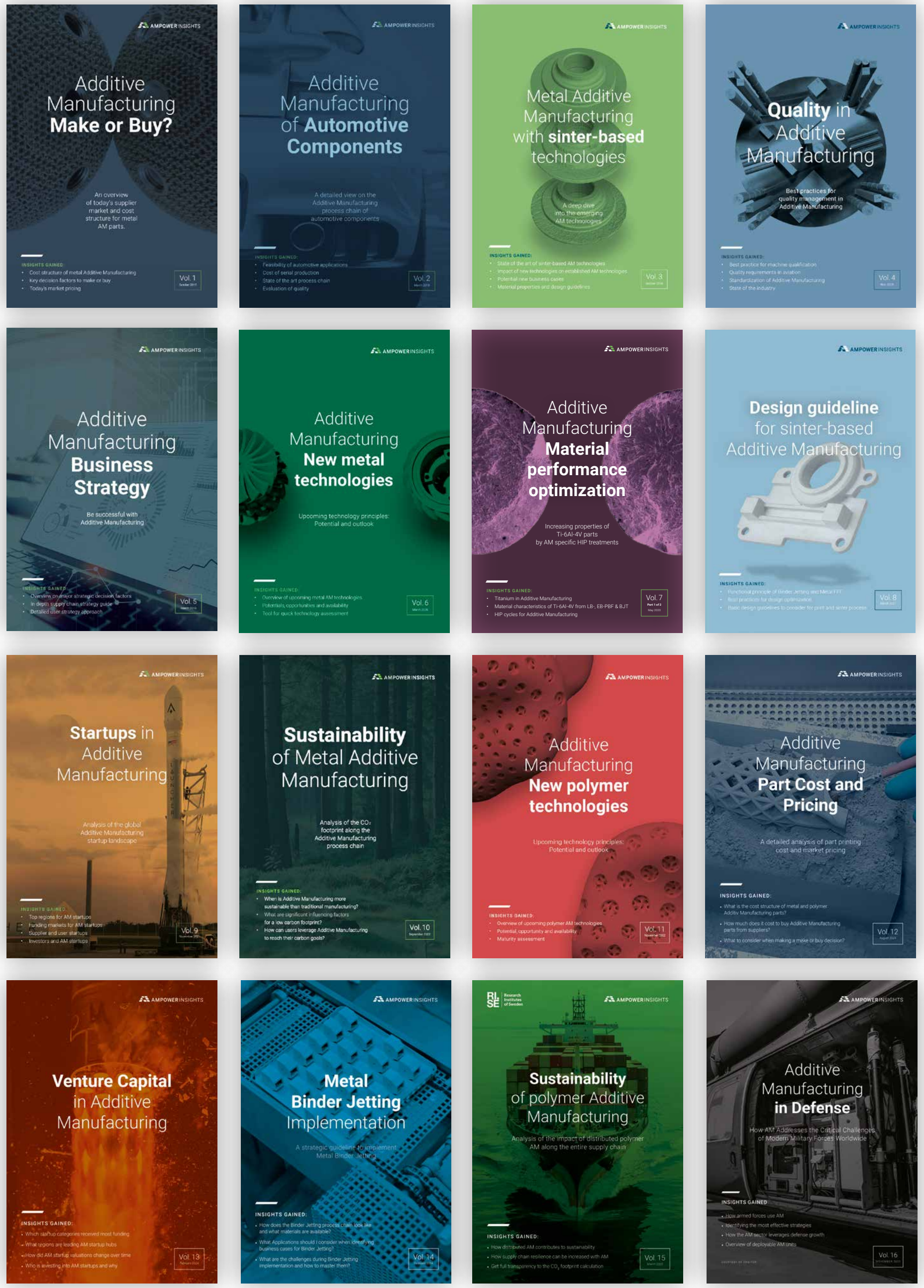
Matthias Schmidt-Lehr successfully managed countless projects in Additive Manufacturing with focus on part screening, business case development, AM design optimization and production in both metal and plastic materials. With a history in the consulting business, he can provide a systematic approach to strategy development and scenario analysis. In his former positions Matthias gathered experience in business development, customer relationship management, as well as marketing and sales.

Dr.-Ing. Eric Wycisk

MANAGING PARTNER AT AMPOWER

Since 2008 Eric successfully supports OEMs from aerospace, medical and automotive to identify Additive Manufacturing applications and implement production capacities in their regulated environments. With a background in topology optimization, titanium alloys and fatigue he is focused on achieving the maximum part performance with the right AM technology.

Missed out on our previous issues?



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Access to the most reliable AM market data

Shortly, after its first release in 2019, the AMPOWER Report became the reference for the Additive Manufacturing industry. It provides a detailed view on the AM market and state of the AM technologies. The AMPOWER Report shows the current market and forecasts the developments expected in the next 5 years.

Features & Benefits

- Based on primary research data from over 300 personal interviews
- Over 100 figures and graphs of AM market data
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- System supplier data based on personal interviews representing over 90 % of the globally installed base
- Online report with all data and figures directly accessible
- Global system, service and powder supplier database with more than 2,400 entries
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