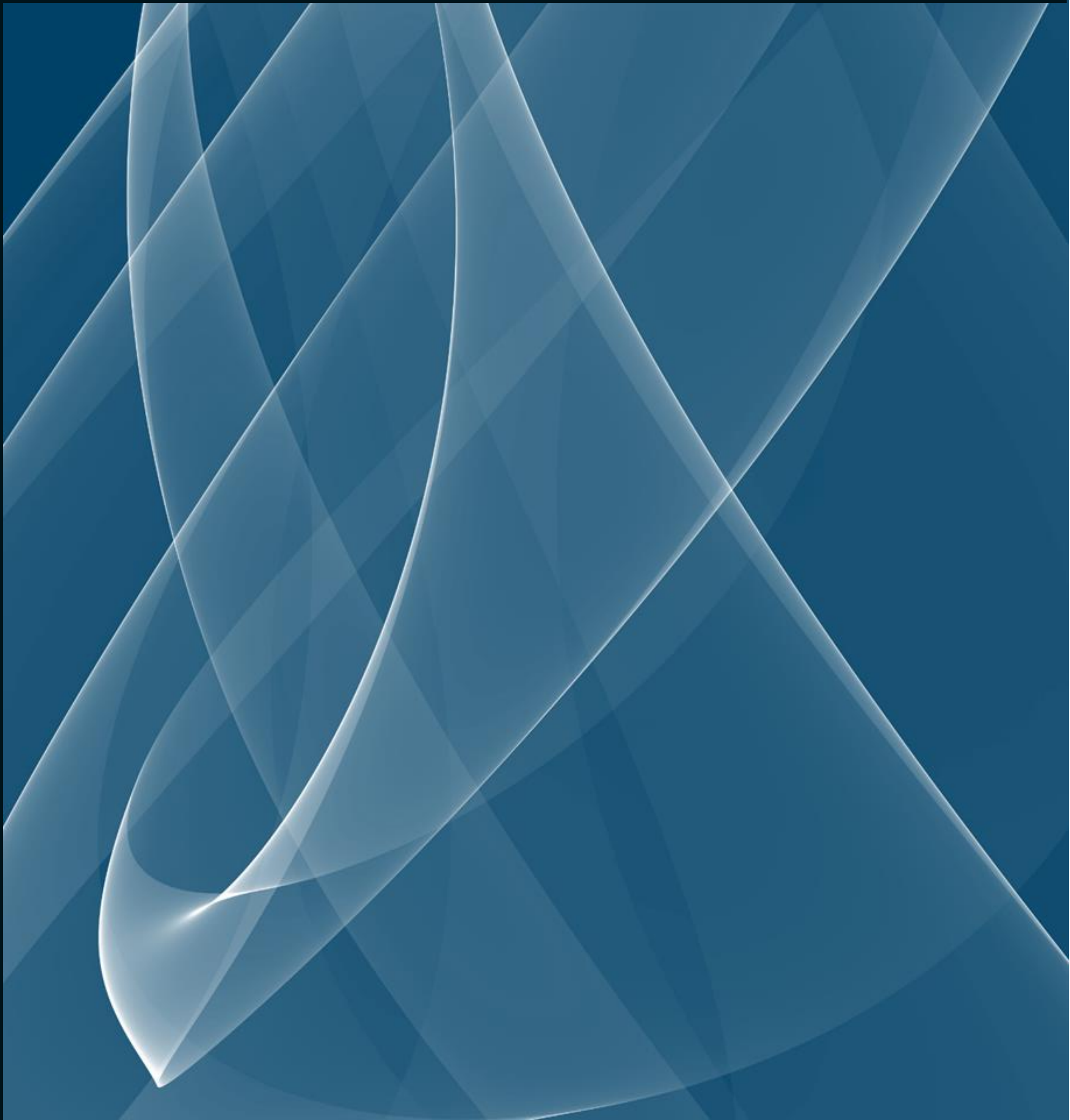
HYBRID CNC PARTS

WHITEPAPER

A Primer on Wire-Laser DED + CNC

The What and Why of Hybrid Manufacturing



Contents

Originally published April 23, 2026, Version 1.0

Executive Summary

Organizations in high-performance industries face unprecedented demands for advanced metal components that traditional manufacturing struggles to meet. Complex geometries, exotic materials, urgent schedules, and strict qualification requirements are pushing conventional production methods to their limits. The result is often long lead times, high costs, late-stage quality failures, and supply chains that cannot deliver critical parts when needed.

This whitepaper introduces wire-laser directed energy deposition (DED or L-DED) combined with CNC machining – a hybrid manufacturing approach – as a practical solution to these challenges.

By integrating additive metal deposition and precision machining in one repeatable workflow, hybrid manufacturing extends conventional CNC processes rather than replacing them, offering new capabilities while preserving the quality and familiarity of established machining practices. The key to making hybrid a sound business decision lies in panning workflow, risk mitigation, and validation as a structured system – turning what was once a novel technique into a reliable manufacturing process.

This primer will help engineering and program managers “see” the hybrid process in action, “prove” that it meets performance and qualification needs, and chart a path to “produce” actual parts at scale.

What this whitepaper explains:

- Traditional manufacturing is struggling to deliver advanced metal parts fast, affordably, and reliably—especially when parts are complex, use tough materials, and must meet strict quality requirements.
- The paper explains a practical alternative called hybrid manufacturing, which combines wire-laser metal deposition with CNC machining.
- It shows how this hybrid approach adds metal and then machines it to final precision in one repeatable workflow, reducing handoffs between vendors/machines.
- It clarifies that hybrid manufacturing doesn’t replace CNC—it extends what CNC can do, enabling new designs while keeping the accuracy and quality controls shops already trust.

1. Why Conventional Approaches & Falling Short

1.1. High Stakes, Low Volume, Hard Materials

Advanced industries such as aerospace, defense, and energy depend on performance-critical parts (turbine components, high-pressure valves, custom tools, precision bearings, etc.) that must withstand extreme conditions.

These parts are often low-volume, highly specialized, and made from hard-to-machine materials (like Inconel superalloys, titanium, or hardened steels). However, delivering such parts with conventional manufacturing (e.g. casting, forging, or subtractive CNC machining alone) has become increasingly difficult.

Many organizations are encountering a growing mismatch between what they need and what traditional methods can reliably deliver.

1.2. "Business As Usual" Can't Keep Up

These issues aren't theoretical; they are daily pain points for engineers and program managers responsible for critical hardware. A recent report on advanced nuclear reactor components, for example, concluded that "conventional methods were cost-prohibitive for small-batch, high-performance [metal] parts" and that no existing supply chain could economically produce certain needed components.

In aerospace and defense, teams have likewise found that certain high-hardness/-strength alloys (e.g. cobalts, hardened steels) or geometrically complex designs simply cannot be produced within required timelines and budgets using traditional fabrication alone.

When lead times stretch out, parts fail to meet spec, or a critical supplier falls through, the impact on programs is severe. Schedule delays, cost overruns, and performance shortfalls force businesses to miss critical milestones with further downstream impacts.

1.3. The Four Gaps

Conventional manufacturing approaches often fail performance-critical part owners in four key areas:

• **Time**	Long lead times
• **Cost**	High material and tooling costs
• **Capability**	Design/material limitations
• **Risk**	Quality/control issues

The rest of this paper explores how wire-laser DED + CNC hybrid manufacturing directly addresses these challenges by providing a unified workflow that reduces lead times and waste, enables new designs and materials, and improves risk management for critical programs.

2. Workflow Integration with the Hybrid Approach

2.1. Best of Both Worlds

Hybrid manufacturing with **wire-laser DED** and **CNC machining** combines the best of additive and subtractive methods in one seamless workflow.

In a hybrid process, a part is built up and machined to precision within the same setup, typically by mounting a laser system and wire feeding toolhead onto a multi-axis CNC platform. This integration allows manufacturers to go from raw material (metal welding wire) to a near-finished, precision-cut part without moving between different machines or vendors.

2.2. The Hybrid Workflow Adds + Subtracts in One Setup

2.2.1. Digital Design & Planning

The process starts with a CAD model of the part, which is then used to generate a combined additive-and-subtractive toolpath. Programmers typically start by creating an “overbuilt” model of the part, adding ~5–10% extra material in areas that will later be machined to final tolerances. Advanced CAM software is used to plan both the deposition and cutting steps in a single program. Critical datums and features are identified up front for machining, ensuring the resulting part meets all dimensional requirements.

2.2.2. Wire-Laser DED

Using the additive toolpath, the hybrid machine’s deposition head feeds standard metal wire (often 0.45 in. diameter welding wire with AWS specification) into a focused high-power laser beam, creating a molten pool that fuses to a base substrate or part-in-progress.

The machine deposits material layer by layer to build up a near-net-shape part. Deposition rates ~0.75-1 lb/hr are high – significantly faster than powder-bed fusion – and the process can be paused as needed for intermediate operations.

2.2.2.1. Metal Wire, Not Metal Powder

The use of welding wire as feedstock brings several advantages: it’s widely available in hundreds of alloys (steel, nickel, titanium, etc.), costs an order of magnitude less than specialized metal powders, and is melted with 100% material utilization (no powder waste or “overspray” at all). Every millimeter of wire becomes part of the build, eliminating the ~30–60% material loss typical in powder-based DED processes.

The wire-laser approach also avoids the safety hazards of fine metal powders. There’s no combustion or inhalation risk, meaning the process can be operated on a standard shop floor without expensive ventilation or explosion-proof equipment.

2.2.3. Integrated CNC Machining

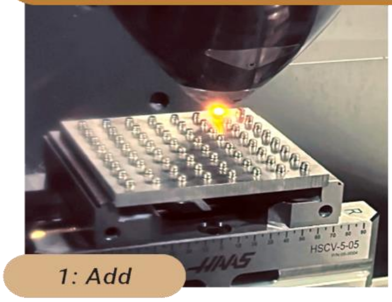
After deposition (or even between multi-step depositions), the same machine performs CNC milling and drilling operations on the part *in situ*.

Thanks to the additive step, complex features that were expensive or impossible to machine from a solid billet can now be efficiently created by depositing near-net geometry and then cutting it to final shape. Machining may occur in alternating sequence (e.g. rough-build, machine critical surfaces, then add more material and machine again) or only after the full additive build is complete – the approach is chosen based on the part's geometry and tolerance needs.

The hybrid machine's multi-axis CNC capability ensures the final part meets precision requirements on critical features like mating surfaces, holes, and tolerances. For instance, internal channels or overhang features can be additively built in shapes that would be inaccessible by cutting, and then other areas are finish machined for accuracy, all within one setup.

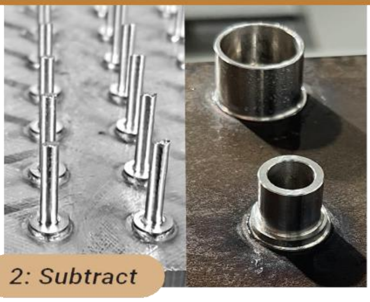
This tightly coupled workflow reduces misalignment errors and preserves fine datums because the part never leaves the machine until it's finished.

Hybrid Manufacturing Process



1: Add

Parts are printed with metal wire feedstock and melted by the laser onto a substrate, building up the component one layer at a time.



2: Subtract

Excess material is removed, part geometry is refined, and a surface finish is achieved using the built-in 5-axis CNC.

3: Finish

Hybrid manufactured parts are durable and precise. The process is well suited to custom, complex, and multi-material components.

More Efficient
Faster with less material waste than powder- or bound-filament additive manufacturing methods.

Performance Materials
Diverse feedstock options including high-performance alloys like Inconel® and Stellite®.

Precise Parts
Produces complex, near-net shape parts with minimal post processing.

Consistent Quality
Fully-dense prints result in strong, durable components.

Versatile Builds
Create new parts, or repair and modify existing ones. Ability to fabricate with multiple materials.

Safety First
Unlike powder-based HM methods, with w-LMD there are no flammable or inhalable toxic materials.

Diverse Part Sizes
HM with w-LMD has the largest build range of any metal additive system.

Innovative Builds
Dual-material printing allows for mixed-alloy components, enhanced with Alloy Composite™ material technology.

This photo shows a hybrid manufacturing cell combining additive deposition and precision machining in a single setup. This Haas UMC-750 is equipped with a Meltio wire-laser DED head and dual wire feeder, enabling near-net material deposition directly onto a substrate or existing part. The same machine then performs multi-axis CNC machining on critical features—preserving datums, eliminating re-fixturing, and allowing complex geometries (internal channels, overbuild-and-machine strategies, and multi-material transitions) to be produced in one continuous workflow.

2.2.4. Optional Heat Treatment & Finishing

Depending on the material, a post-deposition heat treatment (e.g. stress relief or hardening) may be required. In most cases, this happens between setup 1 (additive + rough cuts) and final machining steps.

In some cases, however, the wire-laser process itself produces material properties near equivalent to wrought alloys without additional heat treating. For example, certain tool steels like H13 or H11 can achieve high hardness as-deposited due to the rapid solidification of the weld process, eliminating a separate hardening step.

In these circumstances, the additive process *doubles* as the heat-treating process, eliminating an entire secondary process and the need for refixturing the part after its hardened.

After CNC machining, the part typically requires minimal surface finishing since surfaces have already been milled to spec, unlike as-printed powder-bed parts that often need extensive polishing or machining.

2.3. Key Material & Process Considerations in Hybrid Manufacturing

2.3.1. Material Selection

Hybrid DED processes are compatible with standard industrial alloys available in wire form – from stainless and tool steels to Ni-based superalloys (e.g. Inconel 625/718), titanium alloys, cobalt-chrome alloys (e.g. Stellite), and more. Engineers should select feedstock alloys based on the part's performance requirements (e.g. high-temperature strength, corrosion or wear resistance), just as they would in conventional design.

Because hybrid uses welding-grade wires, material certification and lot traceability are already well-established; these alloys are usually identical to those used in welding/fabrication, ensuring final parts have equivalent chemistry and properties to standard wrought or cast materials.

Furthermore, hybrid machines can be equipped with dual wire feeders to enable on-the-fly material changes or gradient materials. This opens the door to functionally graded components, e.g. depositing a hard wear-resistant alloy on top of a tough structural alloy, but it requires careful process control to prevent cracks and ensure metallurgical compatibility (e.g. matching melting points, thermal expansion, etc.).

2.3.2. Process Parameters & Controls

The wire-laser DED process offers a high degree of control over the resulting microstructure and properties. Adjusting laser power, travel speed, wire feed rate, and bead overlap allows programmers to tune the cooling rates and thermal input, which in turn affect grain structure and material properties in the deposited metal. For example, in one successful hybrid build of a stainless steel hydrogen valve, a precise set of deposition parameters (0.040" layer height, 0.080" bead width with ~30% overlap, ~1.2 kW laser power) was used to ensure a fully dense structure with optimal metallurgy in the as-built 316H stainless steel material.

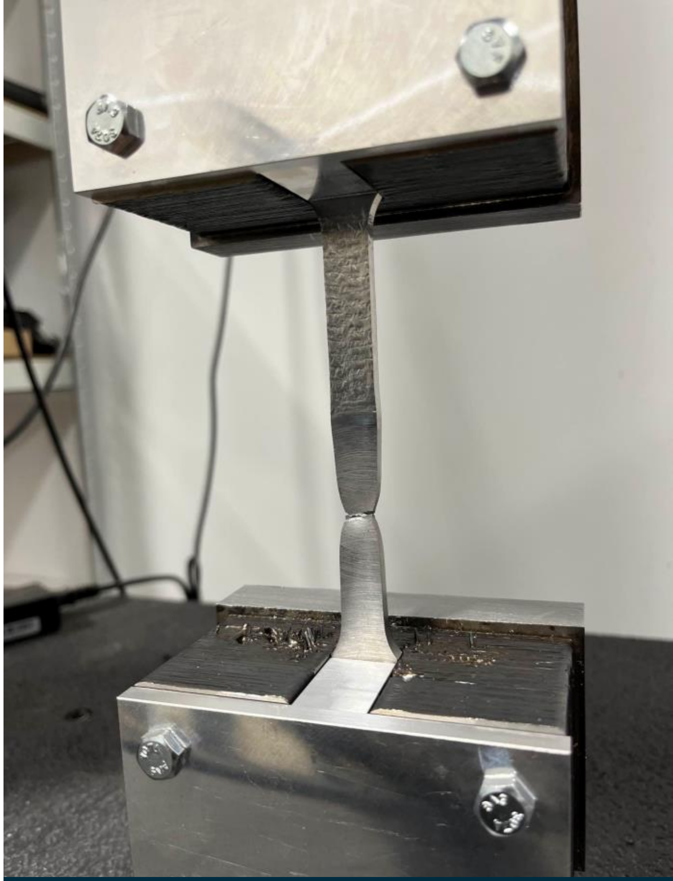
Advanced hybrid systems often incorporate real-time monitoring and feedback control (e.g. melt pool sensors or thermal cameras) to achieve consistent, repeatable deposition results. This focus on controlled, repeatable process parameters is critical – it ensures that when the same part is built multiple times, the outcomes (dimensions, material quality, etc.) remain consistent, which is essential for production acceptance.

2.3.3. Workflow & Operational Considerations

The hybrid workflow reduces the number of distinct process steps and external suppliers, simplifying project management.

Instead of sending a part out for casting/forging, then to a machine shop, then perhaps to a heat treater or welder, hybrid consolidates fabrication into one cell. This does require an investment in new equipment or partnering with a qualified hybrid manufacturing service provider. However, it also means engineers can iterate faster (by simply updating digital toolpaths rather than re-tooling hardware) and even perform multiple design-build-test cycles within weeks.

Hybrid machines can be integrated into existing shop environments; for instance, laser-wire deposition heads like Meltio’s can be retrofitted



Tensile test specimen (dogbone geometry) produced via wire-laser DED and machined to final dimensions, shown after failure under uniaxial loading on a 250 kN Instron system. The specimen exhibits consistent necking and ductile fracture behavior, indicating fully dense material and strong metallurgical bonding between deposited layers. Mechanical performance was validated through controlled process parameters and corroborated by microstructural analysis (including SEM characterization not shown), confirming properties comparable to conventional wrought material. Achieving this level of repeatability requires precise control of deposition, thermal history, and machining strategy within the hybrid workflow.

onto standard CNC machines or robotic arms, allowing companies to upgrade an existing 3-axis or 5-axis mill into a hybrid system.

For those not ready to acquire equipment, working with a specialized hybrid manufacturing service team (such as **Hybrid CNC Parts**, https://hybridcncparts.com) for pilot projects is an effective way to access this capability without major capital expense.

2.4. Hybrid Manufacturing is a Streamlined Process

Overall, the hybrid wire-laser DED + CNC workflow transforms metal fabrication from a sequential, multi-step ordeal into a single, streamlined process. This approach preserves the strengths of CNC precision and quality control while adding the freedom and efficiency of additive manufacturing. Engineers gain new capabilities, building features and using materials that were previously impractical, without abandoning the proven practices of machining and inspection that ensure part quality.

3. Evidence & Qualification Proving Hybrid Works for Critical Parts

3.1. Wire-Laser DED Considerations

Adopting any new manufacturing process for mission-critical applications demands convincing evidence. Performance-critical part owners, whether aerospace engineers, defense procurement leads, or industrial program managers, will ask:

> *How do I know a hybrid-built part will be as good as (or better than) the one I use today?*

In highly regulated sectors, it's not enough for a new technology to theoretically offer benefits; it must prove its capabilities through data, testing, and adherence to industry standards.

3.1.1. Industry Standards

AMS7010 and AWS D20.1 are two prominent standards guiding the qualification of wire-laser DED (sometimes referred to as L-DED by the issuing bodies) processes for critical metal parts.

AMS7010 is an SAE Aerospace Material Specification focused on establishing strict process controls for L-DED (both wire-fed and powder-fed) to produce consistent, aerospace-grade preforms for subsequent machining.

In contrast, AWS D20.1 (AWS Specification for Fabrication of Metal Components using Additive Manufacturing, 2019) is a comprehensive American Welding Society standard covering both powder bed and DED processes; it introduces a graded qualification framework to ensure repeatable, high-quality AM components across multiple industries.

The table below provides a high-level comparison of AMS7010 vs. AWS D20.1, highlighting their approaches to mechanical property qualification, non-destructive evaluation (NDE) requirements, process control parameters, and the technical, cost, and industry perspectives that underlie each standard.

	AMS7010 **SAE Aerospace, L-DED Process Spec**	**AWS D20.1** **AWS AM Fabrication Spec**
Issuing Body	Published by SAE International's aerospace committee (AMS-AM); developed at FAA's request to support **aerospace certification** of AM parts. Geared towards **aerospace & defense** applications, ensuring L-DED preforms meet stringent requirements for flight-critical hardware.	Published by **American Welding Society (AWS)** in 2019 as a cross-industry AM welding code. Developed with input from aerospace, defense, energy, and other sectors to standardize metal AM **qualification and fabrication** practices across industries beyond aerospace (e.g. oil/gas, nuclear).

	AMS7010 **SAE Aerospace, L-DED Process Spec**	**AWS D20.1** **AWS AM Fabrication Spec**
Scope & Coverage	Focuses exclusively on **Laser-DED processes** using wire feed (Class A) or powder feed (Class B) for additive manufacturing. Defines process controls for producing **near-net-shape L-DED preforms** that will later be machined into final parts. Provides requirements applicable to both wire-laser and powder-laser DED but does *not* cover the CNC machining portion of hybrid manufacturing.	Covers **all metal AM processes**, including **powder bed fusion (PBF)** and **directed energy deposition (DED)** (laser, arc, electron beam), with a single unified approach. It introduces **component criticality classes** (Class A – critical; Class B – semi-critical; Class C – noncritical) that determine the rigor of qualification and inspection required for a given part. The standard is broad in scope, applying to **wire-fed laser DED** as one subset of DED, and future addenda (e.g. AWS D20.2) are planned to address wire DED in more detail.

	AMS7010 **SAE Aerospace, L-DED Process Spec**	**AWS D20.1** **AWS AM Fabrication Spec**
Mechanical Properties & Qualification Testing	Relies on **achieving design-specified material properties** for the AM preform/part. The producer must verify through testing that L-DED deposits meet the mechanical performance and **metallurgical quality** required by the component's design or material specification. Emphasizes *process validation via statistical control*: the standard requires a **Process Control Document (PCD)** in which all **Key Process Variables** (e.g. laser power, travel speed, wire feed rate, thermal control) have defined values, tolerances, and monitoring frequency to ensure consistency. **Material property data** (e.g. tensile strength, hardness, microstructure) from qualification builds must demonstrate that the L-DED process can produce properties equivalent to or meeting the **minimum requirements for the intended alloy/application**, as approved by the Cognizant Engineering Organization (the design authority). This approach ties mechanical qualification to the specific requirements of the intended use, rather than providing fixed generic values.	Requires **extensive qualification builds and mechanical testing** as part of a weld-code-style approach. For **machine qualification** in wire DED, a **"standard qualification build" must yield ≥9 tensile test specimens** (coupons) representing different build orientations (vertical, horizontal, etc.) to verify material strength and isotropy. For each critical (Class A) component design, an additional **pre-production test build** (full-size or scaled part with integrated witness coupons) is built and subjected to the same post-processes and then destructively tested. Mechanical tests (tensile, fatigue, hardness, etc.) on these coupons must show that the part's material properties meet or exceed the specified design requirements for its class. AWS D20.1 does not set specific property values for every material; instead, it mandates that the **Procedure Qualification Record (PQR)** demonstrate that the AM process produces material meeting the project's prescribed mechanical properties. Class A parts demand rigorous statistical evidence of properties (often requiring multiple samples and full data documentation), whereas Class C parts have reduced testing demands, reflecting their lower criticality.

	AMS7010 **SAE Aerospace, L-DED Process Spec**	**AWS D20.1** **AWS AM Fabrication Spec**
Nondestructive Examination (NDE) & Inspection	NDE and inspection are implemented per **aerospace quality standards** and defined in the PCD/quality plan. AMS7010 requires that the producer use appropriate **inspection methods (NDE & destructive)** to ensure the L-DED preform's integrity and quality before final machining, in line with aerospace practices. For critical aerospace parts, this typically includes **visual inspection, dimensional checks, dye-penetrant or fluorescent penetrant inspection (FPI) for surface cracks, and volumetric inspection** (e.g. X-ray or CT scans for internal defects) as agreed with the engineering authority. The emphasis is on tailoring the inspection regime to the part's requirements under the guidance of the cognizant engineering organization. Rejection criteria (e.g. acceptable porosity levels, defect indications) would be defined by the customer or related material specifications, rather than explicitly by AMS7010 itself.	Provides **explicit NDE requirements and acceptance criteria** as part of the standard. All parts require **visual and dimensional inspection**; higher classes impose additional NDE methods. For example, **Class A and B components** typically require *surface NDE* such as **penetrant testing (PT)** or **magnetic particle testing (MT)**, and *volumetric NDE* such as **radiographic testing (RT)** to detect internal flaws. The standard also calls for verifying density (to ensure minimal porosity) and may employ techniques like CT or ultrasonic testing as appropriate. NDE inspectors must be qualified per applicable NDE certification standards. AWS D20.1 thus standardizes inspection processes to ensure defects are identified and bounded by class-specific criteria (e.g. tighter defect limits for Class A parts).

	AMS7010 **SAE Aerospace, L-DED Process Spec**	**AWS D20.1** **AWS AM Fabrication Spec**
Process Control & Documentation	Relies on a **company-specific PCD** approved by the aerospace customer's engineering authority. The PCD details all aspects of the L-DED process (machine setup, powder/wire feedstock control, environment, calibration, pre-/post-processing, etc.) and identifies **Key Process Variables** (laser parameters, travel speed, interpass temperature, shielding gas, etc.) that must be controlled within qualified limits. Changes to any key variable or procedure require analysis (substantiation through testing) and **formal approval from the Cognizant Engineering Organization** before implementation. This ensures a fixed, rigorously controlled process for each qualified application, emphasizing **process stability, traceability, and configuration control** in production.	Employs a **welding-code-style documentation** system. A written **Additive Manufacturing Procedure Specification (AMPS)** is required, detailing the exact process parameters, equipment, feedstock, and post-processing for a given part or family of parts. This procedure must be supported by a **Procedure Qualification Record (PQR)** and **Machine Qualification Record (MQR)** documenting the results of qualification builds and tests. The standard provides tables of **essential process variables for DED** (e.g., laser power ranges, travel speed, powder/feedstock characteristics, preheat temps, etc.) and defines how much a variable can change before requalification is needed. It also includes requirements for **operator qualification (Clause 6) –** operators must be trained, tested, and even perform a demonstration build to be qualified to run production. Overall, AWS D20.1 lays out a very detailed, standardized approach to process control and record-keeping (including checklists and forms) to facilitate consistency and audits across different organizations.

	AMS7010 **SAE Aerospace, L-DED Process Spec**	**AWS D20.1** **AWS AM Fabrication Spec**
Usage & Cost Considerations	Primarily adopted by **aerospace OEMs and suppliers** to qualify DED processes for critical components (e.g. engine or structural parts). Its focused approach allows leveraging existing aerospace material specifications and design allowables, potentially reducing redundant testing when such data exists. However, initial qualification still demands significant investment in process development, iterative test builds, and inspections to satisfy aerospace regulators. The cost is justified by the high value and safety criticality of aerospace parts, and the specification's intent is to enable broader **material qualification** databases (so that future projects can use pre-qualified material property data, reducing per-project qualification cost).	Intended for **broad industry use**, including sectors like **energy, maritime, nuclear, and general manufacturing**, in addition to aerospace. Its **graded requirements** (Class A/B/C) let companies tailor qualification efforts to part criticality, avoiding unnecessary cost for noncritical parts. Nonetheless, for high-criticality Class A components, AWS D20.1 requires comprehensive testing and documentation – full **code compliance can entail extensive time and expense**. In practice, complete qualification for a critical AM component (material data development, procedure and machine qualification, NDE, etc.) might incur costs on the order of **millions of dollars before production**. The standard's benefit is in providing a clear, accepted pathway that can be referenced by various industries and regulators (e.g. ASME and API adapting its principles), which can streamline approval and instill confidence in the safety and performance of AM-produced parts.

3.1.2. The Path to Code Cases

Both AMS7010 and AWS D20.1 target the qualification of wire-laser DED processes for safety-critical applications, but they differ in approach and industry alignment.

AMS7010 is an aerospace-focused process specification that mandates a tightly controlled manufacturing process (via a Process Control Document) overseen by the aircraft OEM's engineering authority, ensuring that L-DED preforms consistently meet the required mechanical properties and quality for final aerospace parts.

In contrast, AWS D20.1 is a comprehensive welding-code-style standard for additive manufacturing that covers both DED and PBF. It introduces part classification by criticality (Classes A, B, C) and requires formalized qualifications (machine, procedure, operator) and multi-level testing (NDE and mechanical) to validate that AM components are produced with acceptable, repeatable properties.

Technically, AMS7010 centers on internal process control and leverages aerospace's established quality systems, whereas AWS D20.1 provides explicit uniform requirements (e.g. standard test builds, coupon tests, checklists) to align AM with traditional welding qualification practices.

In terms of cost and implementation, both standards recognize that qualifying a hybrid L-DED process for critical parts requires substantial investment in R&D, testing, and inspection (often seven-figure costs for a full qualification program). However, their frameworks aim to ensure that these efforts result in robust, safe, and economically viable hybrid manufacturing for high-performance applications, providing stakeholders with confidence in the material properties and reliability of L-DED + CNC hybrid components.

All in all, the AMS7010 and AWS D20.1 comparison highlights how professional societies are converging on rigorous yet slightly different pathways to certify wire-laser DED processes – one via aerospace-specific process control and material standards, and the other via a comprehensive, class-based welding code approach. Ultimately, both are essential for driving qualification of hybrid manufacturing for critical industries.

3.2. Practical Considerations

3.2.3. Material Properties & Integrity

The deposited metal must meet the mechanical and metallurgical properties required for the part's function. Extensive testing of witness coupons (small sample pieces built alongside the part) is a standard practice to verify material quality.

For each build or batch, coupons are subjected to tensile tests, hardness measurements, density checks, and microstructural analysis to ensure the hybrid process achieves the required strength, ductility, hardness, and defect-free microstructure. For example, in a hybrid bearing project for a national lab, multiple Inconel 718 witness coupons were printed with the bearings and tested, confirming that as-printed hardness and tensile strength met the design specifications before any post-treatments.

Every batch of critical hybrid parts is validated with such data to guarantee consistency and performance. Additionally, internal porosity is a key concern for any additive process – but wire-laser DED's weld-bead approach inherently yields fully dense material (≈100% density) without pores, as long as parameters are properly controlled.

Third-party analyses (e.g. via CT scans or cut-up metallography) are useful for showing that wire DED parts can achieve density and microstructure on par with wrought metal.

3.2.4. Dimensional Accuracy and Surface Finish

Because hybrid parts are finish-machined in the same setup they are built, they can meet tight dimensional tolerances and surface roughness requirements identical to those made with traditional CNC machining. However, it is important to prove this through measurements.

Critical surfaces on hybrid-produced components are inspected (e.g. CMM dimensional inspection, surface profilometry) to verify that the final geometry matches the engineering drawing. In prior hybrid builds, precision features (bearing bores, sealing surfaces, threaded holes, etc.) have been successfully machined to within +0.0000 / -0.0005 inches of specification, demonstrating that hybrid parts can satisfy the same GD&T and quality standards as conventionally machined parts.

An internal NASA-sponsored study found that integrating wire-laser DED with precision 5-axis CNC enabled complex components with geometric precision and mechanical properties previously unachievable through either conventional methods

This image shows the touch probe of a coordinate measuring machine (CMM), equipped with a ruby-tipped stylus used for high-precision inspection. The probe works by physically contacting a part at defined points, recording exact 3D coordinates to verify dimensions, geometry, and tolerances against the design. By systematically sampling surfaces, it enables accurate measurement of complex features that are difficult or impossible to assess with manual tools.

or powder-based AM alone. This indicates that a properly executed hybrid process not only meets the usual tolerances but can potentially improve certain characteristics (for instance, adding material in strategic locations allowed better designs that improved performance while still hitting all dimensional requirements).

3.2.5. Repeatability and Process Control

Consistency is crucial for production. Decision-makers will need evidence that the hybrid process produces the same result every time under controlled conditions. This is addressed by treating the hybrid DED+machining process like any special process in manufacturing – through formal procedure qualifications, operator training, and in-process monitoring.

Because wire-laser DED is essentially an automated welding process, companies can leverage well-understood welding qualification standards (e.g. ASME Boiler & Pressure Vessel Code) to qualify the procedure and personnel. For example, a procedure qualification might involve building a representative test part or sample under defined parameters, then performing a battery of tests (tensile, fatigue, pressure testing, NDE inspections, etc.) to demonstrate it meets all requirements.

In practice, hybrid manufacturers employ rigorous documentation and inspection protocols – from logging process parameters to capturing in-situ sensor data – to ensure each build is traceable and within spec. Feedback control systems (like melt pool monitors or temperature controls) can actively adjust process settings to maintain quality, further ensuring repeatability.

Over multiple projects and trials, hybrid processes have been shown to produce consistent results: for instance, in multi-material depositions, careful control of travel speed and wire switching has yielded crack-free, well-fused transitions without even requiring post-deposition heat treatment – an impressive testament to process stability.

By sharing data packages from successful hybrid builds (material certs, test reports, process parameters, etc.), early adopters are building technical credibility for hybrid manufacturing within their organizations and industries.

3.2.6. Compliance and Certification

In highly regulated industries (aerospace, energy, medical devices), new manufacturing methods must align with certification requirements. A persuasive body of evidence for hybrid manufacturing includes mapping its outputs to existing standards. Fortunately, wire-fed laser DED has an advantage here: it builds on established welding technology, so many certification pathways (welding codes, procedure qualifications, etc.) are directly applicable.

For pressure-containing hardware, for example, the ASME code Case 3020 (recently enacted) shows a path for qualifying additively manufactured components, largely by treating them akin to weldments and requiring material property data to establish design allowables. This means a hybrid-produced pressure part can be qualified under familiar code rules once sufficient test data (e.g. tensile strengths, creep performance, fatigue life) is generated.

Likewise, aerospace and defense primes are beginning to issue material and process specs for additive manufacturing; a credible hybrid manufacturing program will reference those standards and ideally demonstrate compliance through testing.

Early hybrid manufacturing projects have deliberately focused on generating such evidence: for instance, a Department of Energy project on a 3D-printed hydrogen valve showed that a wire-DED 316H stainless steel valve could pass cryogenic performance tests, laying the groundwork for meeting ASME code requirements and other standards. Each successful pilot becomes a case study that reduces uncertainty for the next application.

A wire-laser DED 316H stainless steel valve body is shown in cross-section (foreground) following destructive evaluation to verify internal density and the absence of pressure-critical defects such as lack of fusion or porosity. The visible internal features and machined interfaces highlight the integration of additive deposition with precision subtractive finishing in a single workflow. In the background, a companion qualification article undergoes cryogenic testing, demonstrating that hybrid-manufactured components can meet performance requirements consistent with pressure-bound applications and emerging ASME code pathways.

3.3. Prove It

By addressing these four areas – material properties, precision, repeatability, and standards compliance – hybrid manufacturing moves from a lab curiosity to a credible production option. The emphasis on data and qualification transforms hybrid manufacturing into a risk-managed, engineering-driven process rather than a leap of faith.

In other words, "Prove it" is at the heart of convincing stakeholders that hybrid works. The final section of this primer discusses how organizations can take the proven principles of hybrid manufacturing and apply them in a real business context, evaluating where it makes economic sense and how to implement it from a pilot project to full production.

4. Techno-Economics & the Path from Pilot to Production

Adopting wire-laser hybrid manufacturing is not just a technical decision, it's a strategic business decision. The technoeconomic case for hybrid manufacturing revolves around balancing cost, time, performance, and risk. In this final section, we outline how to identify high-value opportunities for hybrid ("When does hybrid make sense?") and how to de-risk adoption through a structured pilot-to-production pathway.

4.1. When Does Hybrid Add the Most Value?

Not every part or program will benefit equally from hybrid methods. Based on research and industry experience, hybrid manufacturing delivers the strongest advantages in scenarios where conventional methods struggle the most. Here are common indicators that a project is a good fit for a hybrid approach:

4.1.1. Low Volume / High Mix Production

If you need only a handful of complex parts, conventional processes often become cost-inefficient due to high setup and tooling costs. Hybrid excels here – digital fabrication means you can go from CAD to part without custom fixtures or dies, making one-off and small batch production viable and cost-effective. For instance, a single hybrid machine can produce a variety of different parts in succession just by loading new CAD files, something not possible with a dedicated casting mold or stamping die.

4.1.2. Long Lead Time Items

Parts that typically take many months to source (e.g. waiting for a forging or an overseas supplier) can frequently be produced faster with a local hybrid process. By collapsing multiple steps into one, hybrid manufacturing shortens production cycles. In critical situations where schedule pressure is high – say a grounded aircraft awaiting a replacement part – the cost of delay can far outweigh the cost of the part itself. Hybrid manufacturing provides a way to compress lead times and avoid prolonged downtime.

4.1.3. High Material Costs or Scrap Rates

Components made of expensive materials (tool steels, nickel superalloys, etc.) or those that see most of the input material machined away are prime candidates. In traditional machining, if half or more of a costly billet is cut off as scrap, that is direct wasted expense. Hybrid DED builds near-net shapes that drastically reduce material waste, saving cost and making use of expensive alloys only where needed. Moreover, as noted, welding wire feedstock is dramatically cheaper than metal powders or specialized forgings, and it’s readily available off-the-shelf in a vast selection of alloys. The combination of lower material cost and higher buy-to-fly ratio (finished weight vs. raw material weight) can tip the balance in favor of hybrid for costly metals.

4.1.4. Parts Requiring Enhanced Performance or Multi-Material Zones

Many high-end components need targeted properties, e.g., a wear-resistant surface on a tough base, or a heat-resistant alloy only in certain areas. Achieving this function with conventional methods is complicated (it might require separate parts joined together, or thick coatings that don’t hold up). Hybrid manufacturing allows such functionally graded designs by depositing dissimilar metals in different regions of a part, with controlled transitions between them. For example, a valve seat might seamlessly incorporate a Stellite hardface on a stainless body in one build, or a single bearing race could have an inner section of tough steel and a surface layer of a self-lubricating alloy. These designs can dramatically improve performance (longer wear life, better heat/corrosion resistance) and reduce life-cycle costs. Hybrid is uniquely suited to building them in a single process. (By contrast, a traditional approach might need two separate components joined by brazing or other laborious steps – or the design might be abandoned as “unmanufacturable.”)

4.1.5. High Qualification or Reliability Requirements

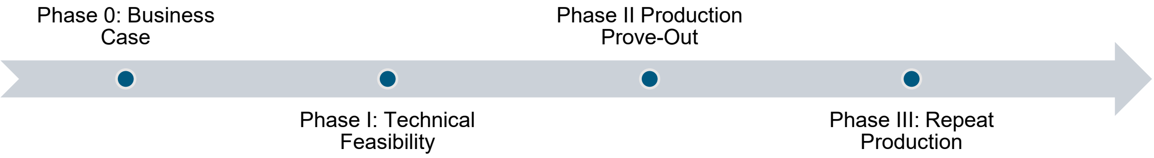
Hybrid manufacturing can reduce program risk in regulated industries by simplifying process chains. Fewer process steps mean fewer opportunities for error and variation. Also, hybrid’s reliance on qualified weld wire inputs and weld-based processes means that compliance gaps are smaller. If you are operating under aerospace or defense quality systems, introducing hybrid manufacturing can be framed as an extension of welding and machining – processes that many organizations already control via specs and certifications. Additionally, when a component is safety-critical, hybrid allows inclusion of built-in quality checks – as discussed, witness coupons, iterative inspections, and a clear digital thread of the entire build process. All of this supports a smoother path through first article inspections, qualification, and customer acceptance.

4.1.6. Supply Chain Gaps or Obsolescence

Hybrid manufacturing is a powerful tool when a needed component is no longer available or no supplier can meet the requirements. This often happens with legacy aerospace and energy systems – e.g. a turbine part or tooling from decades ago that needs replacement, but the original manufacturer is gone or the old drawings call for out-of-stock materials. In these cases, hybrid can recreate or reverse-engineer the part with modern materials and processes. It’s also a way to “get out of the box” of supply chain constraints. For example, when a critical casting is backlogged or an import license is delayed, a hybrid build can serve as a bridge solution (or even a permanent fix) to keep the program on track.

4.2. The Roadmap to Implement Hybrid Manufacturing

Once an organization identifies a potential application that checks the boxes above, the next step is to prove it out through a Pilot Project before scaling up. **Hybrid CNC Parts** strongly advocates a staged implementation to reduce risk and build internal buy-in. A typical Hybrid Manufacturing adoption roadmap looks like this:



4.2.1. Phase 0: Start with the Economics & ROI Considerations

Before any metal is deposited, the hybrid approach can be evaluated on paper. Using known deposition rates, machining times, material costs, and lead time benchmarks, organizations can model the expected return on investment.

Hybrid manufacturing is typically cost-competitive when it significantly reduces lead time or enables a design that delivers performance or risk-reduction benefits that outweigh any incremental cost. In many cases, it can even lower direct costs by eliminating expensive tooling, reducing material waste, and using lower-cost wire feedstock.

For example, a part traditionally hogged from a solid Inconel 718 billet might have a 5:1 buy-to-fly ratio, wasting 80% of the material. With hybrid, near-net deposition can boost yield to ~95%, dramatically reducing raw material costs. Time is another critical factor: in aerospace or energy, a year-long lead time can translate into millions in carrying costs or lost opportunity. If hybrid shortens that to weeks, the avoided costs are substantial.

4.2.2. Phase I: Feasibility Study & First Builds

This phase focuses on proving technical feasibility and establishing a credible path to production. Over 1~3 weeks, the team develops a full digital build package including CAD/CAM programming, manufacturing strategy, and qualification planning.

A small number of parts are built using production-intent parameters, and qualification tests (e.g. mechanical, dimensional, NDE) are run against predefined go/no-go criteria.

The goal is not to optimize cost per part, but to validate that the hybrid process can meet performance, quality, and repeatability requirements. Deliverables include a complete build package, unit economic analysis, and test data. Organizations should expect to invest $30K and up, depending on part complexity, materials, and testing scope. These costs are treated as non-recurring engineering (NRE) and are not representative of production pricing.

4.2.3. Phase II: Production Prove-Out

With feasibility confirmed, the next step is to scale. Phase II transitions the validated process into a production-ready workflow.

The focus is on automation, repeatability, and cost reduction, driving out labor and refining the process for efficiency. This is where the first full production run occurs, using the same equipment, parameters, and quality controls that will be used in ongoing manufacturing.

While some additional NRE may be required (e.g. for automation, inspection, or packaging), these are minimal and tied directly to production needs. Unit costs in this phase reflect true production economics and can be used for long-term budgeting and procurement planning.

4.2.4. Phase III: Repeat Production

At this stage, the hybrid process is fully qualified and commercially viable. Organizations have a proven, documented pathway to produce parts on demand, whether through a dedicated hybrid cell, a qualified supplier, or a hybrid manufacturing partner.

Repeat runs are scheduled as needed, with predictable lead times, stable pricing, and minimal risk.

The result is a robust, scalable supply chain for performance-critical parts that delivers agility, quality, and cost control without compromise.

5. Conclusion

Performance-critical part owners increasingly recognize that hybrid manufacturing transforms production challenges into strategic opportunities. By viewing hybrid not as experimental R&D but as a rigorous, repeatable manufacturing system, companies can make confident business decisions about when and how to use it.

The wire-laser DED + CNC approach allows you to produce complex, fully dense parts before your eyes, prove the results through data and compliance, and then produce real-world hardware with fewer risks and delays.

The **Hybrid Manufacturing Hub** hosted by **Hybrid CNC Parts** (https://hybridcncparts.com) and supported by industry partners, is dedicated to helping organizations navigate this journey.

If you have a candidate part or project that faces the kinds of challenges discussed in this paper, now is the time to evaluate whether a hybrid approach can add value. A logical next step is to engage in a Hybrid Pilot Project – a focused trial that will demonstrate what hybrid manufacturing can do for your specific application. This allows you to obtain tangible results and data with minimal risk and cost.

To learn more or to kick off a pilot, visit the Hybrid CNC Parts website to contact our team for a scoping consultation. By taking that step, you position your organization to leverage the best of both worlds – additive innovation and machining precision – ensuring that you can deliver on the mandate to reduce risk, prove performance, and accelerate production for your most demanding projects.

The era of hybrid manufacturing is here and the decision to embrace it is firmly grounded in commercial reality.

About Hybrid CNC Parts

Hybrid CNC Parts is an advanced manufacturing firm specializing in wire-laser hybrid manufacturing. Established in 2021, it has quickly become a leading producer of precision components for demanding applications.

Hybrid CNC Parts is a fully-owned subsidiary of Multiscale Systems, Inc., a solutions-driven research and design firm integrating engineering expertise with precision manufacturing to solve complex, real-world challenges.

Co-located in Worcester, Massachusetts, Hybrid CNC Parts and Multiscale Systems deliver vertically-integrated design, engineering, and manufacturing capabilities under one roof.

Quality & Compliance

ISO 9001 & AS9100
NIST SP 800-171
DFARS 252.204-7012
CMMC 2.0 Level 2

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