ICAM25

WHITE PAPER

Accelerating Industrial Readiness in Directed Energy Deposition (DED)

Outcomes from the Global DED Luncheon Held at the ASTM International Conference on Advanced Manufacturing 2025 (ICAM25)

October 2025 — Las Vegas, Nevada

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(Image Courtesy of GKN Aerospace and Northrop Grumman)

Prepared under the ASTM Additive Manufacturing Center of Excellence (AM CoE)

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FOREWORD

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Foreword

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The Directed Energy Deposition (DED) process stands at a pivotal moment. As ambitions to transition DED from demonstration to full industrial deployment advance across aerospace, defense, energy, marine, and automotive sectors, the need for robust standards, consistent inspection methods, and shared data frameworks has become increasingly urgent.

This white paper captures collective insights from a DED Luncheon held during ICAM25, where leading practitioners, OEMs, and standards authorities convened to identify key obstacles and define a path forward. The recommendations presented here reflect broad community consensus rather than any single organization's viewpoint.

At **NASA,** additive manufacturing is key to advancing propulsion systems and other mission-critical technologies, with the goal of enabling industrialization. From this perspective, NASA recognizes that community-aligned standards and methods are essential to scaling DED from innovation to routine practice. Achieving this will require balancing rigorous qualification with adaptable pathways for innovation and close coordination among technical stakeholders, regulators, and industry.

NASA is pleased to participate in this collaborative effort with ASTM and industry to advance global DED industrial readiness and strengthen standards development in this important field.

NASA Marshall Space Flight Center
(Contributed by Paul Gradl, Principal Engineer)

About the Editors

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Josh Barras is an Additive Manufacturing Principal Engineer at ASTM International with over a decade of experience in advancing DED technologies. He holds a UKRI Future Leaders Fellowship hosted at ASTM International UK, following four years at TWI Ltd. Through this Fellowship, he introduced high-speed DED to the UK and established facilities to accelerate industrial adoption. His current work focuses on DED process qualification, data frameworks, and industrial readiness within the AM CoE. Josh is a Chartered Engineer (CEng), Member of The Welding Institute (MWeldI), and the first recipient of the EWF International Additive Manufacturing Process Engineer (DED-LB) diploma.

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Executive Summary

At ASTM's International Conference on Advanced Manufacturing (ICAM25), held in Las Vegas on October 6-10th 2025, over fifty representatives from OEMs, Tier-1 suppliers, machine manufacturers, research organizations, and standards bodies convened for the inaugural **DED Luncheon.** The event aimed to launch a global community initiative to accelerate industrial readiness and standardization of DED technologies.

Through live polling, round-table discussions, and a post-event survey, participants identified **three primary themes** as immediate barriers to industrial adoption:

1. **Standards, qualifications, and industrial readiness**
2. **High-quality materials data and allowables**
3. **Process calibration and consistency.**

Participants called for unified standards, consistent qualification frameworks, improved data traceability, and stronger collaboration between machine OEMs, end-users, and standards bodies. The collective output forms the foundation for ASTM's global DED roadmap and highlights community interest in establishing an ongoing forum for DED collaboration within the ASTM Additive Manufacturing Center of Excellence (AM CoE).

Participants also acknowledged the relevance of ASTM's Consortium for Materials Data and Standardization (CMDS) framework in supporting future collaboration and data alignment. In line with the white paper's findings, CMDS has already initiated a new DED workstream focused on addressing the most critical barriers to industrialization. Its structured, consensus-based approach to materials and process data was viewed as a solid foundation for developing the shared understanding needed to advance DED standardization.

Background and Objectives

WHY DED INDUSTRIALIZATION MATTERS

DED offers distinct industrial advantages across repair, large-scale manufacturing (both exceeding and complementing powder bed fusion (PBF)), coatings, casting and forging replacements, feature addition, hybrid manufacturing, and multi-material processing. Despite rapid technological progress, DED adoption has not kept pace with PBF, due to the lower availability of commercial systems, high entry costs, substantial knowledge requirements, and limited access to standardized workflows and qualification pathways.

DED's potential spans multiple sectors, including aviation, energy, automotive, and defense. However, fragmented best practices and standards, high qualification costs, significant entry investments, and the siloed nature of data generation continue to slow large-scale adoption. ASTM's AM CoE aims to address these challenges by developing a cohesive ecosystem of standards, data infrastructure and sharing frameworks, and qualification pathways that enable reproducible, certifiable, and economically viable DED production.

OBJECTIVES OF THE LUNCHEON

The DED Luncheon was conceived as a pilot for launching a global DED user community, aligning industry, academia, SDOs, government bodies, and regulatory agencies toward shared goals:

- Define common industrial priorities and technical barriers.
- Harmonize qualification and certification frameworks across sectors.
- Strengthen data and calibration standards.
- Foster collaboration through mechanisms such as ASTM CMDS.
- Build a collective voice for DED in regulatory and funding discussions.

Methodology

SESSION STRUCTURE

The luncheon followed a structured, five-phase format designed to balance context, discussion, and feedback. Each phase, summarized in the table below, progressively built toward identifying shared priorities and next steps for the DED community. The round-table discussions formed the core of the session, enabling consensus-building and capturing collective viewpoints that informed the closing synthesis.

Table 1 – Luncheon Objectives

Phase	Objective
Scene Setting	Establish context on DED maturity and ASTM's global initiatives
Live Poll	Rank top barriers and priorities for industrialization
Round-Table Discussions	Deep dive into top three community-selected themes
Report-Back & Synthesis	Capture key messages from each table
Final Survey & Roadmap Input	Collect organizational perspectives and commitment levels

PARTICIPANT DEMOGRAPHICS

Approximately **fifty experts from thirty-five organizations** participated in the inaugural meeting, representing a cross section of aerospace, energy, and industrial sectors including OEMs, Tier 1 suppliers, machine builders, and SMEs, alongside standards bodies, research institutions, and defense organizations. Attendance was impacted by the U.S. government shutdown, which limited participation from agencies such as NASA and the DoD. The session was structured to establish an industry-driven foundation for guiding the community's future direction, reflecting its global reach and industrial diversity. The table below reflects the composition of attendees at the DED Luncheon.

Table 2 – Participants

Category	Percent	Notes
OEMs	22 %	Boeing, Lockheed Martin, Pratt & Whitney (an RTX Business), Rolls-Royce, Northrop Grumman, MHI
Tier-1 / Energy Integrators	20 %	GKN Aerospace, Siemens Energy, Baker Hughes, Technip FMC, Solar Turbines
SMEs & Service Providers	7%	DEEP Manufacturing, RPM Innovations Inc, Etxetar
Machine & Equipment Suppliers	19%	Oerlikon, Makino Asia, Ponticon, MX3D, Meltio, Addup, HMT, Formalloy
Standards / Research Bodies	18 %	ASTM, Wohlers Associates, NMIS, America Makes, MMPDS, Fraunhofer Institute for Laser Technology ILT, RWTH Aachen University – Digital Additive Production DAP
Government / Defense Stakeholders	14 %	MOD, Aerospace Corporation, Sandvik, Babcock

* Participants represented organizations from across North America, Europe, and Asia (including Singapore and Japan), reflecting DED's global relevance. The participant table includes those who provided permission and is not exhaustive; some organizations span multiple categories but are counted only once.

Live Poll: Community Priorities

Participants ranked the key barriers to DED industrialization across eight predefined topics. The weighted scores shown below represent normalized averages of participant rankings, where higher values indicate greater perceived impact. An opportunity to question and debate these topics was provided during the round-table discussions, and participants noted significant overlaps among several of the themes in practice.

Table 3 – Themes and Ranking

Rank/Theme	Weighted Score*	Interpretation
1: Standards, qualification & industrial readiness	3.3	Fragmented standards and heavy qualification burden are the top barrier
2: High-quality materials data & allowables	2.8	Traceable, high-fidelity data is critical to design and certification
3: Process calibration & consistency	2.6	Reliable calibration and repeatability underpin confidence
4: Testing & inspection	1.8	Desire for risk-based, less destructive approaches
5: In-process monitoring & control	1.5	Key enabler for future digital qualification
6-8: Post-processing, digital frameworks, tool pathing	<1.3	Lower priority, more process-specific

The top three priorities guided the round-table discussions, while the remaining topics will be examined in future forums given their continued relevance to DED adoption.

Round Table Discussions and Findings

STANDARDS, QUALIFICATION, AND INDUSTRIAL READINESS

Current Landscape

DED qualification frameworks remain fragmented, reflecting both gaps in dedicated standards and variability in how existing specifications are applied. Many organizations continue to use general additive manufacturing standards or adapt welding-based specifications (e.g., AWS D20.1, AWS D17.1) and PBF-oriented documents (e.g., ISO/ASTM 52904) for DED applications. Among the few DED-specific standards, AMS 7010A defines requirements for laser directed energy deposition (L-DED) processes using powder and wire feedstocks.

ASTM recognizes these gaps and is bringing the community together to pursue more consistent and harmonized approaches to DED qualification. While frameworks such as AWS D20.1 provide a foundation, DED remains less mature, presenting a need and opportunity for greater alignment across sectors.

Although statistically robust materials data (allowable and accessible) remains a long-term goal, the table above indicates that it is not the most immediate barrier to DED adoption. **Nevertheless, high-quality materials data are fundamental to developing credible standards and qualification frameworks,** as they underpin design allowables, process validation, and inspection criteria. Some participants emphasized, however, that testing and inspection consistency should rank even higher, as it currently presents a greater limitation to industrialization. Without reliable inspection correlation to those datasets, allowables cannot effectively de-risk higher-criticality applications.

Key Issues Identified

- Absence of a unified, dedicated DED standards framework.
- Inconsistent terminology and definitions across standards bodies.
- High qualification cost and duplicated testing, with limited confidence that existing allowables and inspection methods cover real DED geometries and build variability.
- Insufficient operator training and calibration programs.

Community Recommendations

In parallel with improvements to testing and inspection, the community reached consensus on several actions to strengthen data integrity and reusability.

- Develop a **common dictionary** of DED terminology and qualification metrics.
- Publish ASTM guidelines harmonizing AWS, AMS, and ISO approaches, and aligning where practical with external frameworks (e.g., NASA-STD-6030), to promote consistent terminology and qualification structures across sectors.
- Encourage **performance-based (“not worse than”)** equivalency frameworks.
- Create formal training and certification for DED operators and inspectors.
- Build collaborative workshops for cross-sector qualification alignment.

HIGH-QUALITY MATERIALS DATA AND ALLOWABLES

Current Landscape

DED materials data remains limited in statistical depth and traceability. Proprietary "black box" datasets hinder validation and reuse, while variations in feedstock quality (powder or wire) and incomplete process metadata obscures the relationships between process parameters, resulting microstructure, material properties, and performance outcomes, including post-processing effects such as heat treatment.

Key Issues Identified

- Limited baseline and statistically valid data for key alloys (e.g., IN625, IN718, Ti-6Al-4V) continue to show variability across heat treatment and processing routes (e.g., stress relief, HIP). While recent publications have expanded the available datasets, the cost and true need for HIP remains debated, and broader validation is still required to support criticality-based decisions.
- Lack of standardized powder and wire specifications (PSD, chemistry, morphology, cleanliness).
- Inconsistent chemical composition limits across processes create challenges—overly narrow ranges in DED can increase cost and requalification frequency, while wider ranges in powder-based processes can complicate data generation and allowables development.
- Limited access to high pedigree databases or shared repositories.

Community Recommendations

- Establish a shared, globally accessible DED data framework linking feedstock/process/structure/properties/allowables/heat treatments, designed to protect IP and account for machine variability through calibration and equivalency measures, recognizing that further community input is needed to define practical approaches acceptable to all stakeholders.
- Require full metadata capture and independent verification of dataset pedigree.
- Integrate QMS audits to ensure data provenance.
- Balance material specification stringency to enable flexibility and broader supplier participation, while ensuring comparability through calibration and equivalency practices defined collaboratively to protect IP and maintain OEM fairness.

PROCESS CALIBRATION AND CONSISTENCY

Current Landscape

Process variability between machines and suppliers undermines confidence in DED qualification. Few organizations apply structured installation, operational and performance qualification (IQ/OQ/PQ) frameworks. Long build durations can create drift and inconsistency if not carefully controlled.

Process calibration was highlighted as a major gap, especially in aerospace, where machine OEMs must help define and verify performance metrics. Participants emphasized that calibration consistency also matters across other industries, i.e., energy and automotive sectors, suggesting that future standards should be adaptable across domains to ensure broad uptake.

Key Issues Identified

- Absence of standard calibration procedures across machine OEMs.
- Limited monitoring process, e.g., process, thermal, and condition monitoring.
- Limited third-party audit or certification frameworks for integrated DED machine calibration (e.g., feed delivery, thermal input, kinematics, motion control), though related activity is being developed by certification bodies such as NADCAP and ASTM.
- Over-reliance on destructive testing for verification beyond first-article qualification stages.

Community Recommendations

- Define a **three-tier calibration hierarchy** (machine, process, component) to align verification practices and traceability across systems and builds.
- Develop standardized calibration artefacts within the three-tier calibration hierarchy to link machine and process performance with part-level properties, accounting for wall-thickness sensitivity (particularly challenging for testing thin-walled components by powder DED).
- After qualification, use control-chart and non-inferiority testing to confirm process equivalency across machines, materials, and sites.
- Promote real-time, in-situ process monitoring and bounded control for production assurance.
- Align IQ/OQ/PQ frameworks, as defined in AMS7032, with related guidance from ASTM, AWS, and other frameworks (e.g., NASA-STD-6030) to promote consistency in process qualification and control.

CROSS-CUTTING THEMES

Trust and Transparency

Open collaboration in data sharing and standard interpretation can yield significant efficiency gains and cost savings compared to siloed efforts.

Training and Competency

Operator certification is vital to consistency and scaleup.

Digital Infrastructure

AI, monitoring data, and digital twins are seen as key enablers of predictive qualification, complementing ongoing international initiatives (e.g., ISO 23247) on digital thread and smart manufacturing, but all depend on robust, high-quality data acquisition and datasets and intelligent interpretation.

Community Formation

Dedicated support for ASTM to formalize a DED initiative, underpinned by ASTM programs including the launch of the DED Workstreams within the CMDS and the Additive Manufacturing Certification Committee (AMCC).

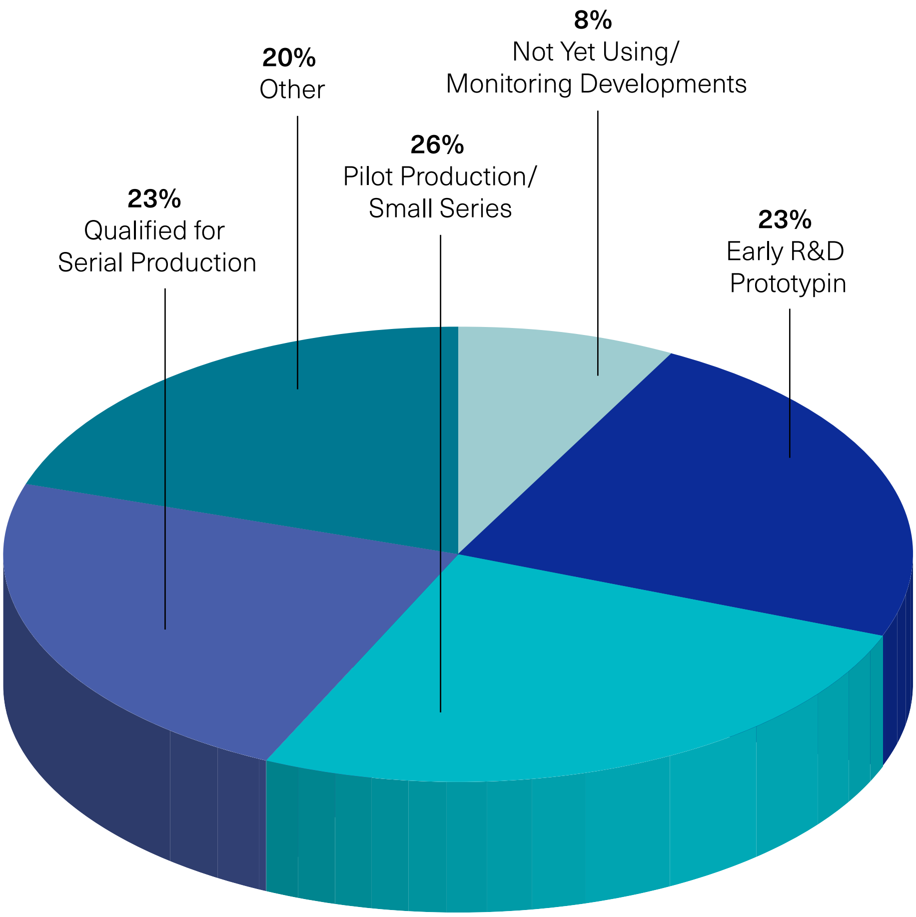
Post-Event Survey Analysis (35 Responses)

Following the luncheon, participants completed a structured online survey to capture individual feedback and quantify community priorities. Thirty-five responses were received, providing valuable insight into industrial maturity, technical focus areas, and the community's readiness to collaborate within ASTM. A summary of key findings is presented below.

ORGANIZATIONAL MATURITY IN DED

Responses showed that 70% of organizations represented are operating beyond early research and development (R&D) stages, with many already engaged in pilot or serial production (see Figure 1). This indicates that DED is progressing from experimental technology toward industrial integration. Approximately one in four respondents reported having a qualified DED process for serial production—an encouraging indicator of readiness, yet one that still underscores the complex path to certification and remaining system gaps. DED-LB (powder) and DED-Arc dominate process usage, confirming broad multi-modality engagement.

Figure 1 – Organizational Maturity in DED
Distribution of respondents across five DED maturity stages; nearly 70 % beyond R&D phase.
Source: ASTM ICAM25 DED Luncheon Post Event Survey (n = 35)



TECHNOLOGY AND PROCESS FOCUS

Most respondents reported engagement across multiple DED modalities. DED–Laser Beam (powder) was the most common, followed by DED–Arc (WAAM) and DED–Laser Beam (wire). A smaller fraction reported activity in High-Speed DED (a newer form of powder DED–LB, also known as EHLA – Extreme High Speed Laser Application), with the lowest participation from DED–Electron Beam (wire). The distribution reflects both the diversity of current market offerings and the geographical and sectoral makeup of the luncheon participants.

Over 60% of respondents expect to expand into additional DED modalities, indicating continued diversification and cross-technology exploration within the community. This metric will be revisited in future workshops as participation broadens across industrial sectors to build a more comprehensive view of DED adoption and application trends.

Many organizations reported parallel interest in other large format additive manufacturing processes, including **Cold Spray, Additive Friction Stir Deposition (AFSD), and especially large-format PBF,** underscoring the convergence of technologies aimed at high-throughput, repair-capable, or large-geometry applications.

BARRIERS TO ADOPTION AND EXPANSION

When asked to identify the greatest barriers to DED industrialization, respondents most frequently highlighted standards, qualifications, and certification as key obstacles—particularly around operator standards, testing, and inspection (see Figure 2). Material development, workforce skills, and cost-related factors followed closely, showing that challenges span both technical and implementation domains. These findings mirror the live poll results from the luncheon and emphasize that many of these barriers can only be addressed through shared standards, collective data, and community-driven consensus.

Figure 2 – Top Barriers to DED Adoption
Primary barriers ranked by frequency; standards, qualification and certification were most frequently cited, followed closely by material development, workforce skills, and cost considerations. Source: ASTM ICAM25 DED Luncheon Post Event Survey (n = 35)

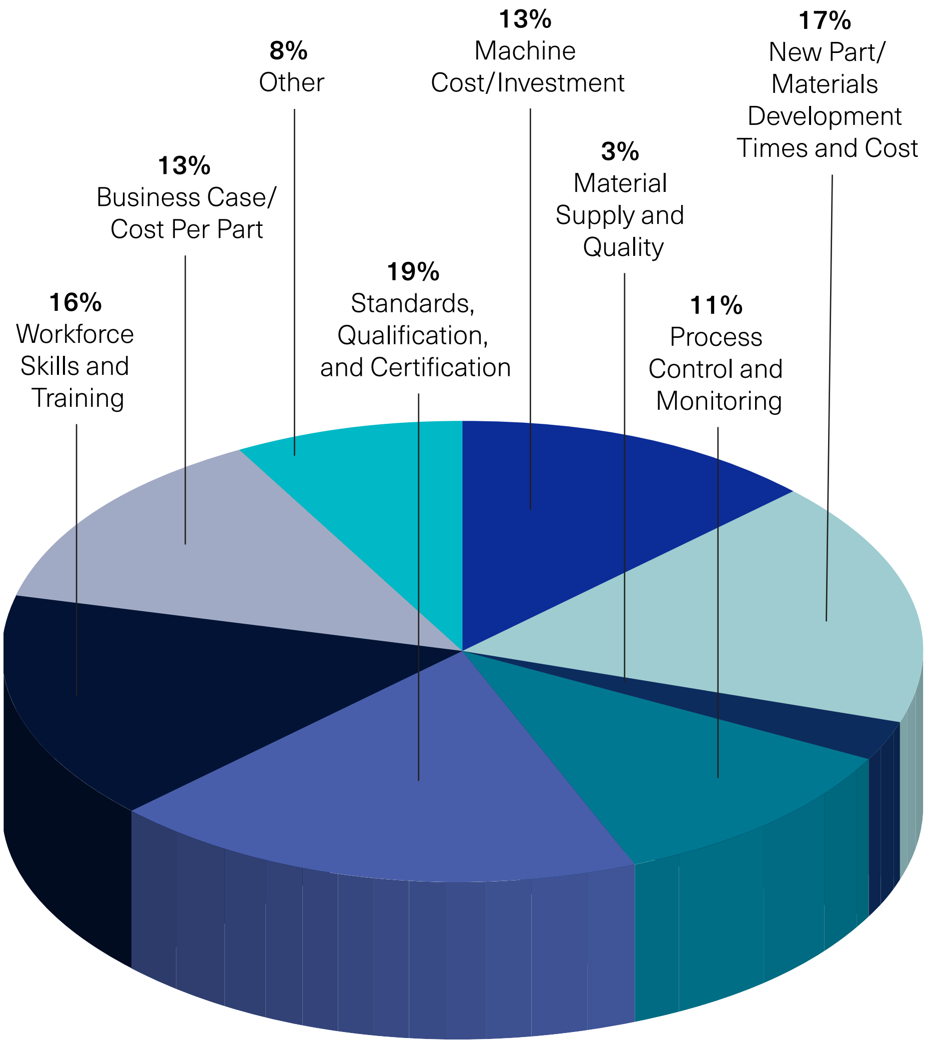


Figure 3 – Standards Gaps and Immediate Needs
Source: ASTM ICAM25 DED Luncheon Post-Event Survey (n = 35)

INTEGRATION Guidelines, harmonization across industries and welding standards, acceptance criteria, cross-industry alignment, aerospace specifications, allowables, and best practices	**PEOPLE AND SKILLS** Operator training and certification
PROCESS Inspection, testing, calibration, process calibration, machine monitoring, IQ OQ PQ, and qualification	**FOUNDATIONAL** Standards, equivalency, framework

In open-text responses, participants elaborated on these themes, grouping their priorities into four tiers **(1) Foundational, (2) People and Skills, (3) Process, and (4) Integration,** illustrating how standards development, qualification, and competency must evolve together to achieve full industrial readiness for DED (see Figure 3).

1. **Foundational** elements such as standards, equivalency, and framework establish the baseline structure and terminology that underpin all higher-tier activities.
2. **People and Skills** emphasize consistent operator training and certification, recognizing that human competency remains central to reliable production and credible qualifications.
3. **Process** priorities encompass inspection, testing, calibration, and structured qualification (IQ/OQ/PQ), supported by machine monitoring to ensure repeatability and comparability across systems.
4. **Integration** focuses on unifying guidance and best practices across industries and welding standards, including harmonization of acceptance criteria, aerospace specifications, and statistically based allowables.

Furthermore, these tiers could offer a useful basis for exploring links between traditional welding-based qualification principles and emerging DED-specific standards and workflows.

STANDARDS AND EQUIVALENCY OUTLOOK

Most participants favored selective or shared equivalency across the different DED processes (26 % saw strong parallels, 40 % favored selective equivalence, 17 % distinct, 17 % unsure), acknowledging that while each modality has distinct features, many qualification principles could potentially overlap. In this context, equivalency was interpreted pragmatically as the ability to demonstrate comparable quality or qualification outcomes across DED process types when supported by validated data and process controls, rather than implying regulatory interchangeability. Equivalency assessments rely on clear pedigree in calibration, best practice, data, and testing, reinforcing the need for the CMDS DED Program to drive consensus-based activities and deliver high-impact standards. Operator certification and component inspection standards were identified as the most urgent needs, with several respondents suggesting these should form early deliverables for the new ASTM DED guideline initiative.

ENGAGEMENT AND RESOURCES

The survey revealed strong momentum for community participation. Over three quarters of respondents indicated readiness to engage directly with ASTM and its activities. Most organizations were prepared to contribute staff time to working groups, and half were open to data sharing or pilot part provision under NDA.

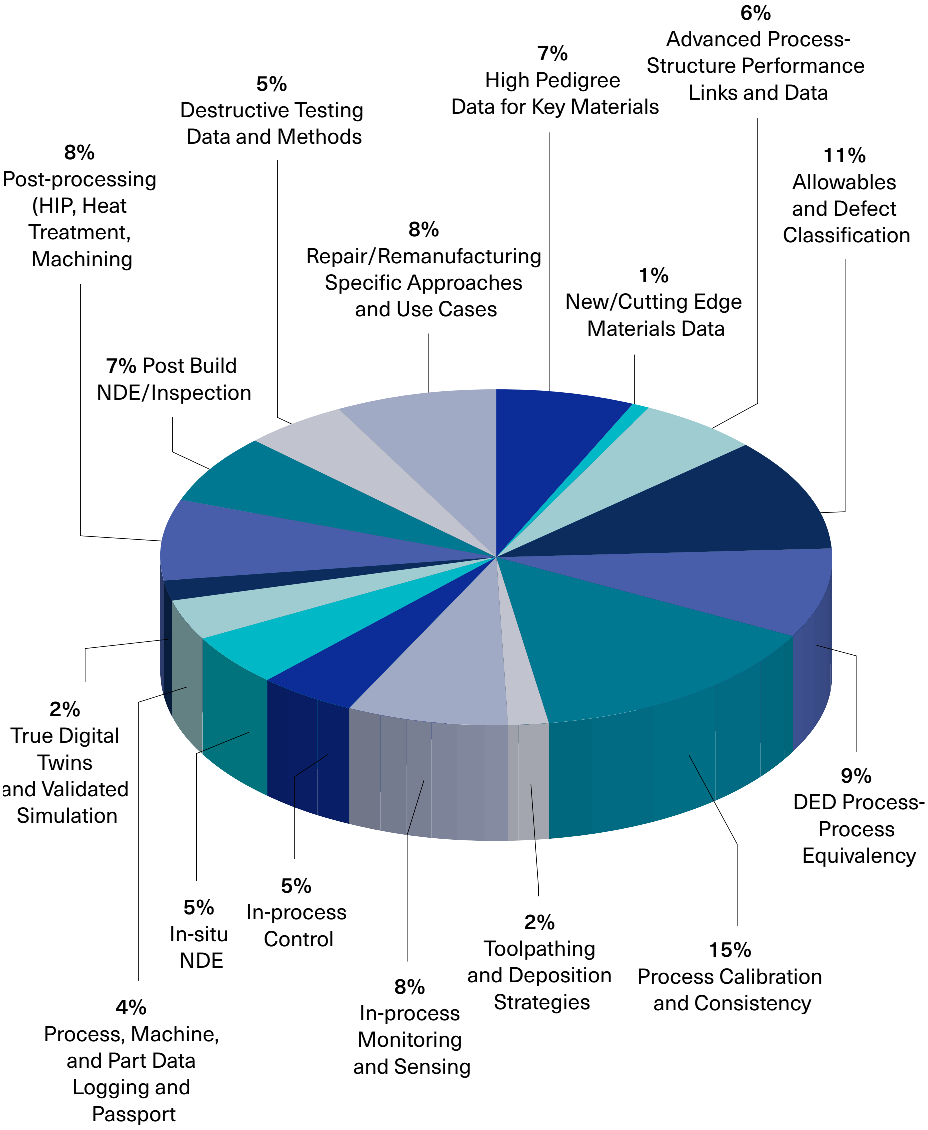
Among respondents expressing interest in continued engagement, several identified the ASTM CMDS framework as an effective vehicle for collaboration and data exchange. They noted its potential to tackle key DED barriers by fostering stronger partnerships, generating high-pedigree data, and advancing standards readiness.

PRIORITY TECHNICAL AREAS FOR COLLABORATION

Figure 4 illustrates how respondents ranked potential project topics. Process calibration and consistency emerged as the highest priority (15%), followed by allowables and defect classification (11%) and DED process-to-process equivalency (9%). Areas such as tool pathing and deposition strategies, repair and remanufacturing specifications, and post-processing (HIP, heat treatment, machining) each received strong interest at around 8%, while high-pedigree data for key materials and post-build NDE/inspection followed closely at 7%. Lower but still notable attention was given to advanced process-structure-performance data, in-situ NDE, process monitoring and control, and digital-thread logging and passporting. True digital twins and cutting-edge materials data were identified as longer-term interests.

These findings closely mirror the round-table discussions at ICAM25, reaffirming broad alignment on where ASTM and industry should initially focus collaborative work. The spread of responses also indicates that consensus is still forming on how to sequence these priorities—underscoring the need for continued dialogue to define a shared roadmap for coordinated DED standardization and data alignment.

Figure 4 – Priority Technical Areas for Community Projects
Process calibration and consistency received the most votes, followed by allowables/defect classification and equivalency. Results represent input from this initial event and will be refined as further community feedback is collected. Source: ASTM ICAM25 DED Luncheon Post Event Survey (n = 35)



DESIRED OUTCOMES

Respondents were asked to identify the outcomes they most wanted for future ASTM DED initiatives to deliver. The results indicate emerging alignment around establishing a strong technical foundation for growth, though further data and discussion will be required to confirm wider community consensus.

Technical confidence, grounded in reliable data and robust standards, ranked as the highest priority (26 respondents), followed by **industrial integration and supply-chain readiness** (21 votes) and **strategic influence through funding and policy engagement** (19 votes). **Workforce readiness,** including operator training and certification pathways, also featured strongly (17 votes).

These results underline that while strategic visibility and workforce development remain important, **industry confidence built on data integrity and standardization** is viewed as the essential first step toward wider DED adoption.

COMMUNITY FORMATION AND NEXT STEPS

An overwhelming 91% of respondents expressed support for ASTM facilitating a sustained DED community under the AM CoE umbrella. Suggested formats included a Community of Practice or Industrial Users Group.

In terms of engagement, **52%** of participants saw strong alignment with ASTM's goals and indicated readiness to engage actively, through staff time, data sharing, or pilot-part contribution. A further **26%** expressed interest but emphasized that clear *rules of engagement* and defined working structures would help them participate more confidently. Around **11%** indicated they were interested but wanted the initiative to move beyond introductory themes toward tangible, project-based activities, an encouraging sign that the community is eager for focused outcomes rather than conceptual discussion. The remaining **11%** did not currently see direct benefit, which is likely to reflect the position of early adopters already advancing DED programs, but who may connect later as shared standards and guidance evolve.

Respondents also described, in their own words, what motivates participation and what additional focus areas ASTM should consider. Recurring themes included ***collaboration, clarity of purpose, standards alignment,*** and *funding opportunities*. Over half **(57%)** expressed explicit interest in participating in international collaboration mechanisms through the ASTM AM CoE.

When asked if any important topics were missing from the luncheon, most respondents indicated that the session was comprehensive and well structured. Some suggested deeper focus on inspection and testing, cross-industry collaboration, and more discussion time for technical debate. Several participants also highlighted sector-specific interests including automotive, medical, and energy, which could be revisited in upcoming community meetings.

In summary, the survey results confirm a maturing, motivated, and globally distributed DED ecosystem eager to collaborate through ASTM. The feedback validates the luncheon's three core themes and underscores the need for structured programs on standards harmonization, calibration guidance, and transparent pedigree data.

Feedback will inform ASTM's upcoming DED roadmap and shape the structure of ongoing community collaboration. Participants asked that the roadmap be treated as a living document with periodic updates delivered through a convening mechanism to be defined by ASTM.

Conclusions and Recommendations

The combined roundtable and survey results reaffirm the community's shared priorities for advancing DED industrialization **(1) standardization, (2) data infrastructure, (3) calibration, and (4) workforce capability,** and show a clear appetite for continued collaboration under ASTM's facilitation.

Participants also stressed the importance of **coordinated input from OEMs, regulators, RTOs, and sector bodies** to ensure any emerging standards or guidance documents remain interoperable and practical across aerospace, defense, energy, marine, and automotive domains.

Moving forward, the community identified eight priority areas that could form the basis for discussion within future working groups and collaborative initiatives:

These shared priorities will form the basis for continued discussion and prioritization within future collaborative activities coordinated through ASTM AM CoE.

1. **Unify Standards and Terminology**
   Explore development of a harmonized framework linking AWS, AMS, and ISO references, accompanied by a shared dictionary of DED terminology.
2. **Enable Data Transparency and Reuse**
   Support creation of a federated DED database or shared data infrastructure under the CMDS framework, with defined metadata and validation protocols.
3. **Establish Calibration and Qualification Guidance**
   Develop common approaches to calibration and process qualification (IQ/OQ/PQ), including artefact-based benchmarks and sector-appropriate verification methods.
4. **Adopt Performance-Based Equivalency Models**
   Clarify the distinction between **prescriptive** and **performance-based** specifications, recognizing that the preferred approach varies by sector and application. Encourage development of **equivalency frameworks** that enable "not-worse-than" comparisons, supported by statistical validation and digital monitoring, to promote **risk-based qualification** across processes.
5. **Strengthen Training and Certification Pathways**
   Expand Operator and Inspector qualification schemes aligned with ASTM E2659 and certification workforce frameworks.
6. **Formalize an Industry Network**
   Maintain an open, cross-sector platform for ongoing collaboration, prioritization, and roadmap development.
7. **Integrate Digital Assurance**
   Investigate how monitoring, AI, and digital-twin systems can enhance process verification and reduce reliance on destructive testing.
8. **Validate Through Community Consensus**
   Use future workshops and surveys to periodically confirm priorities and ensure harmonization and calibration remain universal focal points.
9. **Expand Community Dialogue to Define the Roadmap**
   Continue structured discussions, workshops, and consensus-based meetings to refine the DED roadmap, ensuring priorities are validated through broader community input and supported by representative data.

Outlook and Acknowledgments

The ICAM25 DED Luncheon confirmed that the global DED community is ready to accelerate industrialization through structured collaboration. Participants expressed strong interest in forming a sustained working group under ASTM's AM CoE framework to discuss, align, and address the challenges identified in this report. ASTM intends to explore the most effective mechanism for sustaining this dialogue—potentially through a recurring forum or community structure.

Rather than prescribing immediate deliverables, the next phase should focus on prioritization and coordination, identifying which topics require shared frameworks and where individual DED technologies may need distinct approaches. Future discussions should include technology-specific stakeholder sessions (e.g., laser-powder, laser-wire, and arc-based DED) to promote impartiality, enable cross-referencing between related processes, and recognize where distinct pathways require separate attention.

Participants also recommended exploring whether adjacent large-scale additive processes such as Cold Spray and Additive Friction Stir Deposition (AFSD) could be included within the same collaborative framework. While not classified as DED under ISO/ASTM 52900:2021 Additive Manufacturing – General Principles and Vocabulary, their inclusion could strengthen cross-learning in deposition control, repair applications, and qualification methodologies. Cold Spray presently sits outside all AM family definitions, though future revisions to terminology could consider expanding DED to encompass directed kinetic energy deposition.

Several participants emphasized the value of developing a shared definition of DED to promote consistent terminology and a common reference point across related domains—while cautioning that excessive overlap or reclassification of solid-state processes could re-introduce the very complexity and inconsistency such efforts seek to reduce.

To sustain the international engagement seen at ICAM25, future activities should broaden to include Research and Technology Organizations (RTOs), universities, and innovation institutes. Their involvement will help maintain scientific depth, ensure aligned directives between research and industry, and connect DED standardization with global academic and business communities.

Building on ICAM25 discussions, contributors highlighted ASTM Standards Committee F42 on Additive Manufacturing Technologies as a principal forum for coordinating standardization efforts and ensuring alignment with existing additive and welding-related standards. Participants noted the growing traction of DED–Arc, driven by accessibility, lower investment cost, and strong alignment with welding practices. Future standards within F42 should incorporate perspectives from welding engineers and process integrators alongside powder-based specialists. As DED–LB (wire) technologies mature and costs decrease, the DED process families may become increasingly interchangeable across a wider range of applications. A balanced approach across all DED modalities will be essential to enable greater process flexibility and reflect differing levels of market readiness and technological maturity.

The outcomes summarized in this white paper provide a foundation for deeper consultation. ASTM plans to facilitate follow-on workshops and stakeholder events, such as at Formnext 2025 (Germany), ATI Conference 2025 (UK), and AMUG 2026 (US) to refine priorities, gather wider feedback, and define how a neutral, industry-driven platform for DED and related processes should evolve. By keeping this initiative inclusive of all relevant technologies and stakeholder groups, the DED community can continue building confidence, comparability, and consistency, ensuring that future standards, guidelines, and data frameworks reflect the shared priorities of global industry and research alike.

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Appendix A List of Acronyms

Table 4 defines key acronyms and abbreviations used throughout this white paper.

Table 4 – Acronyms (Appendix A)

Acronym	Definition
AFSD	Additive Friction Stir Deposition
AI	Artificial Intelligence
AM	Additive Manufacturing
AM CoE	Additive Manufacturing Center of Excellence (ASTM)
AMCC	Additive Manufacturing Certification Committee (ASTM)
AMS	Aerospace Material Specification (SAE International)
ASTM	ASTM International
AWS	American Welding Society
CEng	Chartered Engineer
CMDS	Consortium for Materials Data and Standardization (ASTM)
DED	Directed Energy Deposition
DED-Arc	Arc-based Directed Energy Deposition (e.g., WAAM)
DED-LB	Laser Beam Directed Energy Deposition
DoD	U.S. Department of Defense
EB	Electron Beam
EHLA	Extreme High-Speed Laser Application
ESA	European Space Agency
F42	ASTM Committee on Additive Manufacturing Technologies
ICAM25	International Conference on Advanced Manufacturing
IQ / OQ / PQ	Installation Qualification / Operational Qualification / Performance Qualification
ISO	International Organization for Standardization
L-PBF	Laser Powder Bed Fusion
MOD	UK Ministry of Defence
NDA	Non-Disclosure Agreement
NDE	Non-Destructive Examination
OEM	Original Equipment Manufacturer
PBF	Powder Bed Fusion
QMS	Quality Management System
R&D	Research and Development
RTO	Research and Technology Organization
SPC	Statistical Process Control
SME	Small and Medium-sized Enterprise
UKRI	United Kingdom Research and Innovation
WAAM	Wire Arc Additive Manufacturing

Appendix B
Referenced Standards and Guide

Table 5 lists the standards, specifications, and guides that were referenced or discussed during the ICAM25 DED Luncheon and appear in this white paper. This is not an exhaustive list but includes those specifically raised or cited in session discussions.

Table 5 – Reference Standards

STANDARD / GUIDE	DESCRIPTION
ISO/ASTM	
ISO/ASTM 52900:2021 Additive Manufacturing – General Principles and Vocabulary	Defines terminology and classifications for additive manufacturing processes.
American Welding Society	
AWS D20.1 Additive Manufacturing – Specification for Fabrication of Metal Components	Provides requirements for metal AM fabrication using welding-based approaches.
AWS D17.1 Specification for Fusion Welding for Aerospace Applications	Sets standards for fusion welding in aerospace; often referenced where DED is treated under welding qualification frameworks.
SAE International	
AMS 7010A Laser Directed Energy Deposition Process Requirements	DED using powder or wire feedstock.
AMS 7032 Machine Qualification for Fusion-Based Metal Additive Manufacturing	Defines requirements for additive manufacturing process qualification and control (including IQ/OQ/PQ methodology).
NASA	
NASA-STD-6030 Additive Manufacturing Requirements for Spaceflight Hardware	Establishes additive manufacturing requirements for spaceflight hardware.
ASTM International	
ASTM E2659 Practice for Certificate Programs	Outlines requirements for personnel training and certification programs.
ASTM Committee F42 on Additive Manufacturing Technologies	Coordinates global additive manufacturing standards development.

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