In situ inspection of Laser Powder Bed Fusion (LPBF) parts using Electromagnetic Sensors

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AMiquam

Who we are

- Company developing in situ inspection for advanced manufacturing (metal PBF-LB)
- Reducing inspection costs and delays
- Founded in 2020 as a spin-off from ETH and Sensima, an NDT company
- Project with inspire, Fraunhofer, ETH, ESA, etc.
- Active commercial projects in Aerospace, Medtech, and Energy sectors
- Contribute to new industry standards
- Designs approved by machine manufacturers, with full product integration achieved with GFMS (DMP350)
- Released the W1 product in 2021, with the W2 product set for release in 2024.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Innosuisse – Schweizerische Agentur für Innovationsförderung

ETH zürich

HORIZON EUROPE

inspire

dilapro DIGITAL LASER PRODUCTION

esa

EUREKA innovation across borders

mtc

canton de vaud LIBERTÉ ET PATRIE

Office for Economic Affairs and Innovation (SPEI)

Pulsate

The problem/The solution

- 30% to 50% of the fabrication costs plus significant delays are caused by post process part inspection
- Leightweight and efficient 3D printing designs are uninspectable
- Critical components (aero, space, medtech) require stringent methodology for inspection

➔Interesting 3D printable components do not reach their market because of inspection

➔Our solution: integrate established NDE technique in the process

From monitoring to inspection

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Levels	Description	Contribution to the following qualification steps
0	Machine input variables	Machine (IQ)
1	Input key process variables (laser power)	Process (OQ)
2	Ouput key process variables (melt pool properties)	
3	+corrective actions	
4	Process anomaly detection, process signatures correlated with flaw with a certain probability (spatter induced lack of fusion)	
5	In situ inspection	Part (PQ)

In situ inspection

- What techniques are available ASTM 3166:20

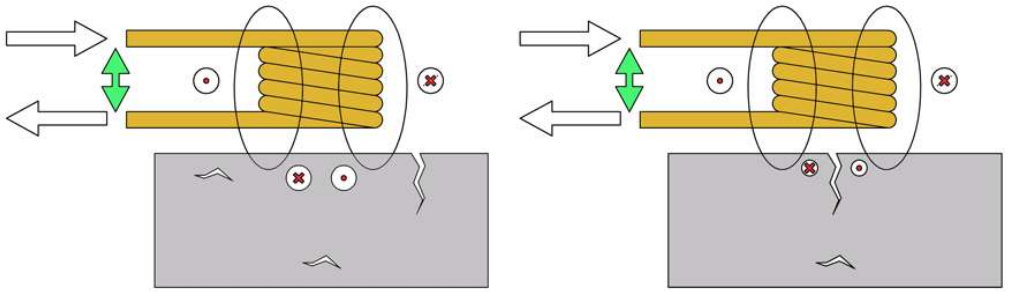
TABLE 3 Application of NDT to Detect Additive Manufacturing Discontinuity Classes[A]

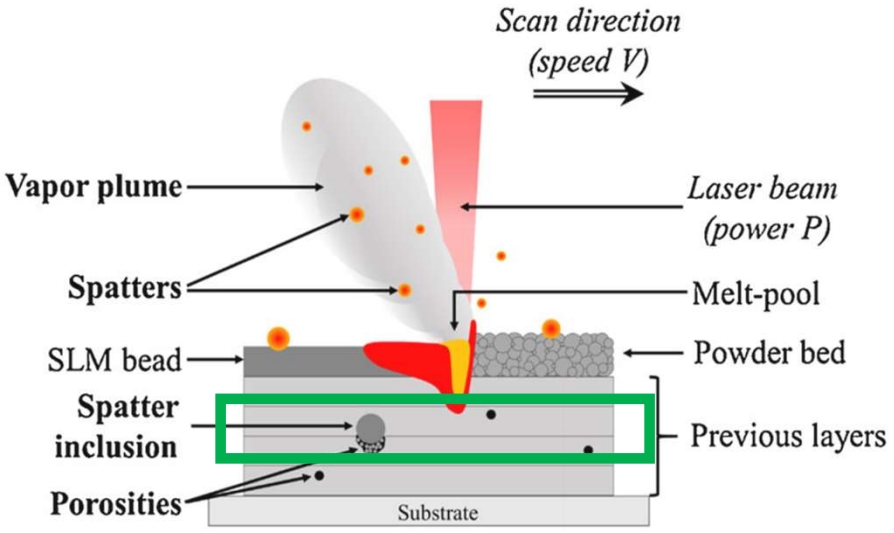
	Covered in this Guide							Not Covered in this Guide				
Discontinuity Class	CT/RT/ CR/DR	ET	MET[B]	PCRT	PT	IRT	UT	AE	LT	NR	MT	VT
Surface	X[C]	X[D]	X	_	X[D]	_	_	_	_	_	_	X
Porosity	X	X[D]	_	X	X[D]	_	X	_	_	_	_	X
Cracking	X[E]	X[D]	_	X	X[D]	X	X	X	X[F]	_	X	X[G]
Lack of Fusion	X[E]	X[D]	_	X	X[D]	X	X	X	_	_	X	_
Part Dimensions	X	_	X	_	_	_	_	_	_	X[H]	_	_
Density[I]	X[J]	_	_	X	_	_	_	_	_	_	_	_
Inclusions	X[K]	X[D]	_	X	_	X	X	_	_	_	_	_
Discoloration	_	_	_	_	_	_	_	_	_	_	_	X
Residual Stress	_	X[D,L]	X	X	_	_	_	_	_	X	_	_
Hermetic Sealing	_	_	_	_	_	_	_	_	X[F]	_	_	_

[A] Abbreviations used: _ = not applicable, AE = Acoustic Emission, CR = Computed Radiography, CT = Computed Tomography, DR = Digital Radiology, ET = Eddy Current Testing, IRT = Infrared Thermography, LT = Leak Testing , MET = Metrology, MT = Magnetic Particle Testing, NR = Neutron Radiography, PCRT = Process Compensated Resonance Testing, PT = Penetrant Testing, RT = Radiographic Testing, UT = Ultrasonic Testing, and VT = Visual Testing.
[B] Includes Digital Imaging.
[C] Especially helpful when characterizing internal passageways or cavities (complex geometry parts) for underfill and overfill, or other internal features not accessible to MET, PT, or VT (including borescopy).
[D] Applicable if on surface.
[E] Radiographic methods are not optimal for detecting tight laminar features like cracking and LOF, which typically do not exhibit enough density change.
[F] If large enough to cause a leak or pressure drop across the part.
[G] Macroscopic cracks only.
[H] Conventional neutron radiography (NR) allows determination of internal and external dimensions.
[I] Pycnometry (Archimedes principle).
[J] Density variations will only show up in imaged regions having equivalent thickness.
[K] If inclusions are large enough and sufficient scattering contrast exists.
[L] Residual stress can be assessed if resulting from surface post-processing (for example, peening).

NDT with Eddy Currents

- Principles: ac magnetic fields generate currents in the part
- Advantages of EC for metal LPBF: non contact, integration
- Purpose of examination: discontinuities and more
- Standardisation efforts for AM: ASTM/ISO and FAA
- Detection limits: PoD





What can be measured with Eddy Currents

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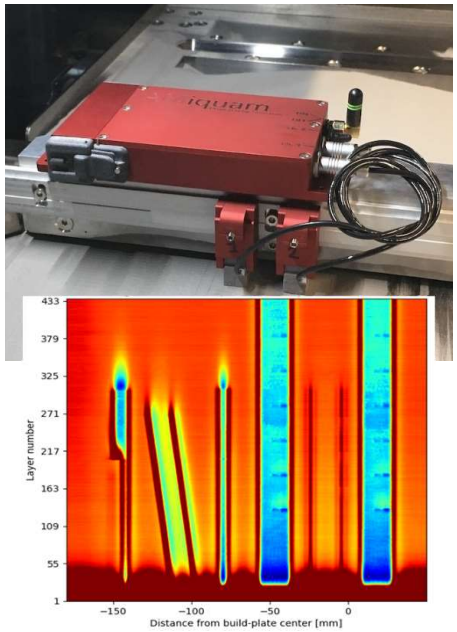
ISO 15549, purpose of examination	Application to metal PBF-LB	Project example
to reveal discontinuities in the product which could affect its fitness for purpose;	See ASTM 3166 (cracks, pores, lack of fusion, inclusions, etc..), rogue flaws	Inspire, DILAPRO, MTC, ESA,…
to measure the thickness of coatings or layers;	Monitoring of process, SPC	Software development
to measure other geometric characteristics;	Detection of cold cracking, prevent part failure, lattice integrity, heat exchangers, hybrid manufacturing	Volum-e, HESSO-VS, TH Rosenheim
to measure metallurgical or mechanical properties of the product+sort products	In situ monitoring of mechanical performance, reduce coupon mechanical tests	Fieldmade
to measure the conductivity and/or permeability of the product;	Measure porosity	EOS, Zeiss, Constellium, Rosswag
+ to measure residual stress	Prevent part failure, reduce HIP	Uni Pavia

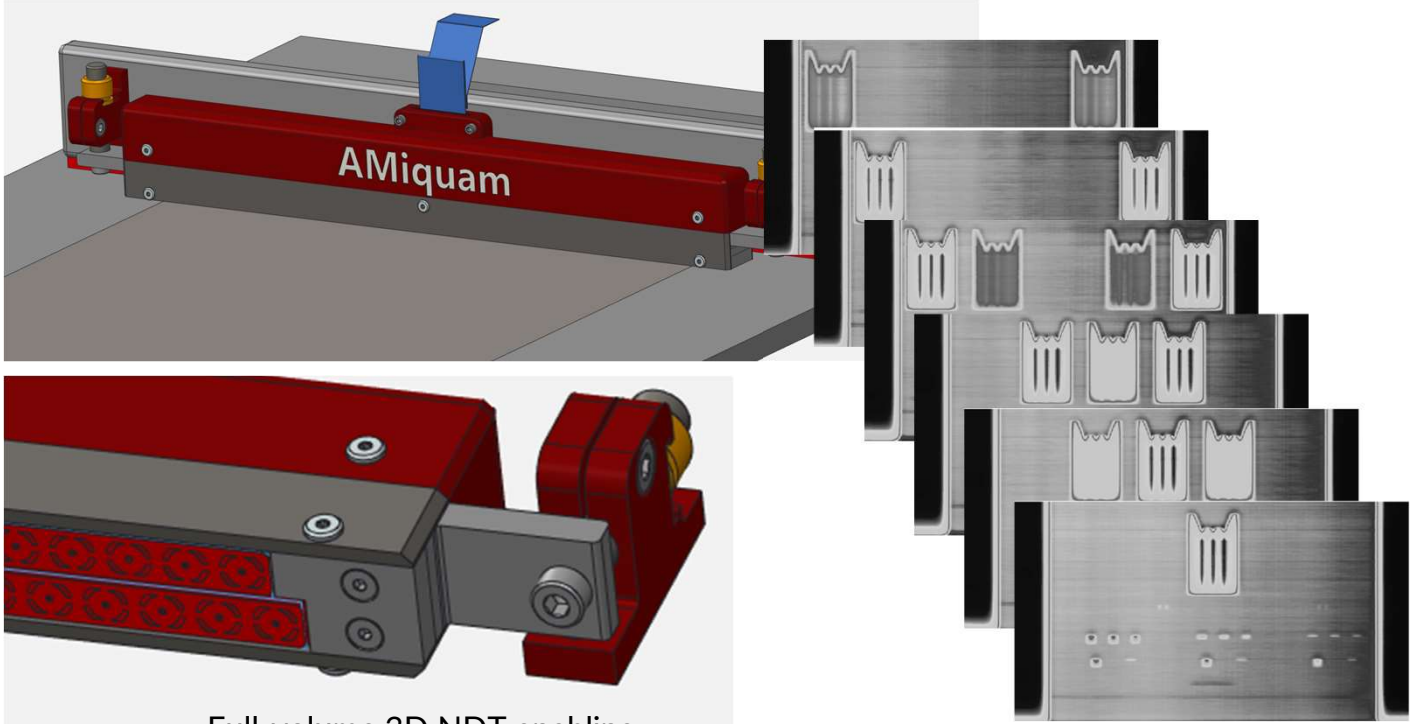
Machine integration

AMiquam W1



Process monitoring providing unique subsurface information on material properties

AMiquam W2 NDT

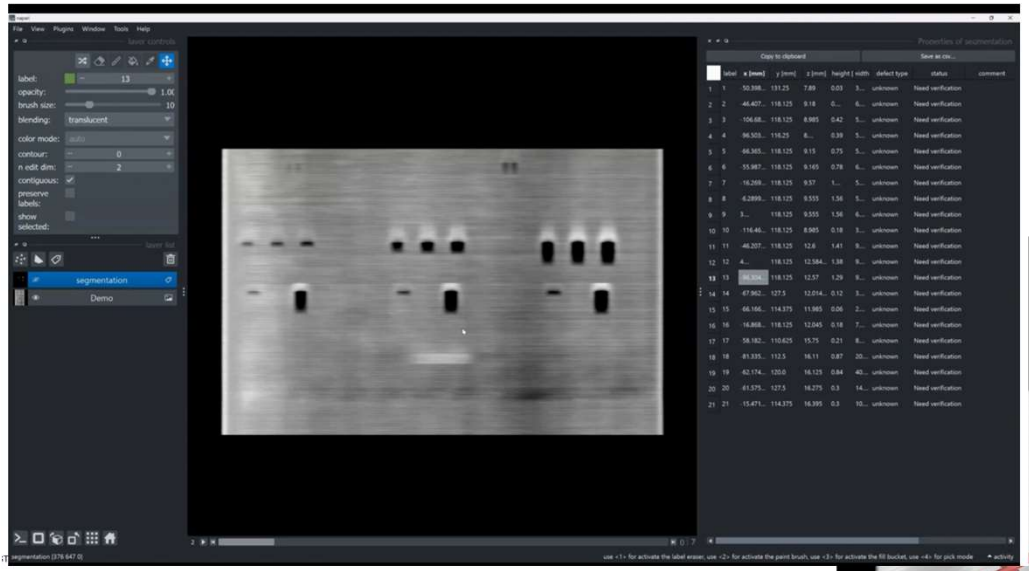


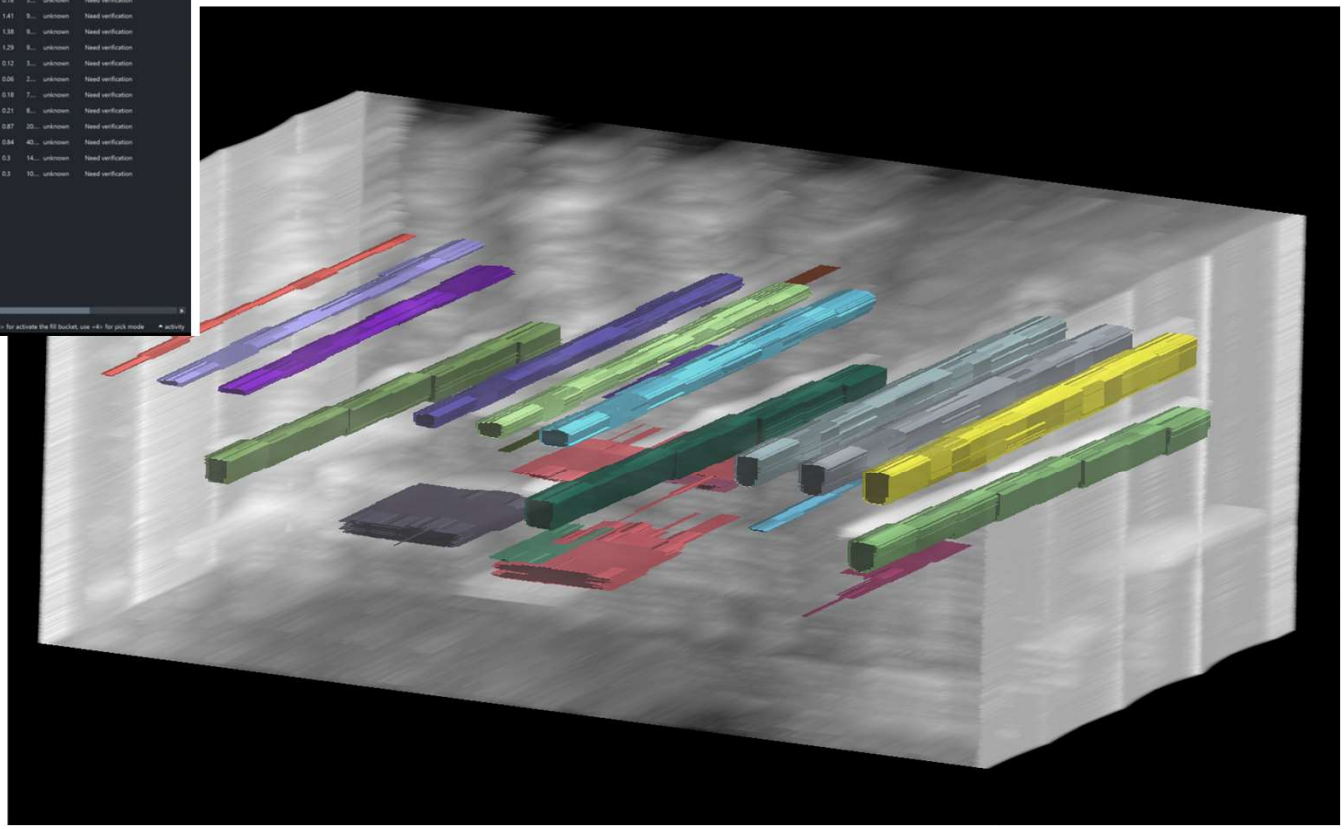
Full-volume 3D NDT enabling part certification

2021

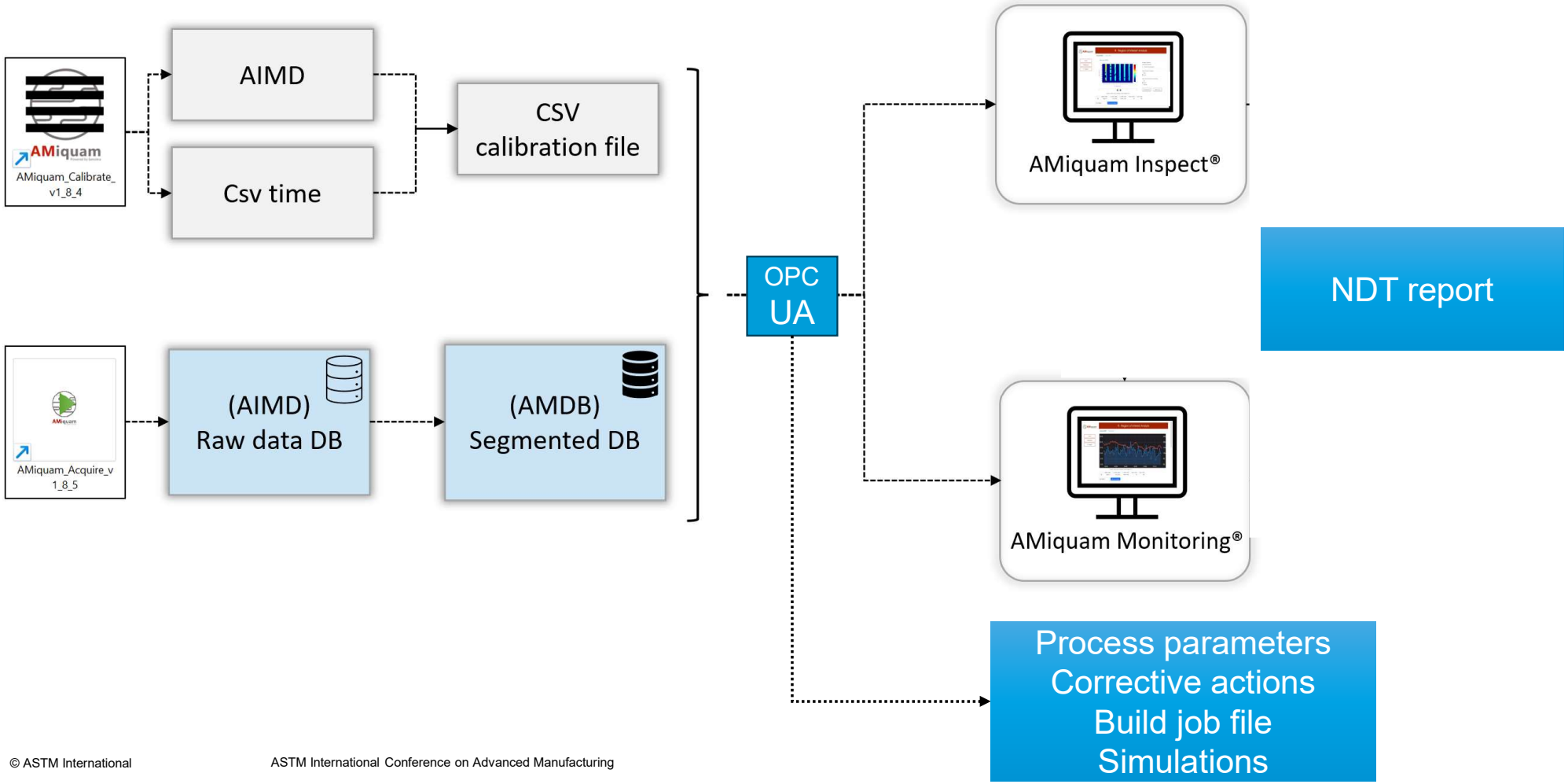
2024

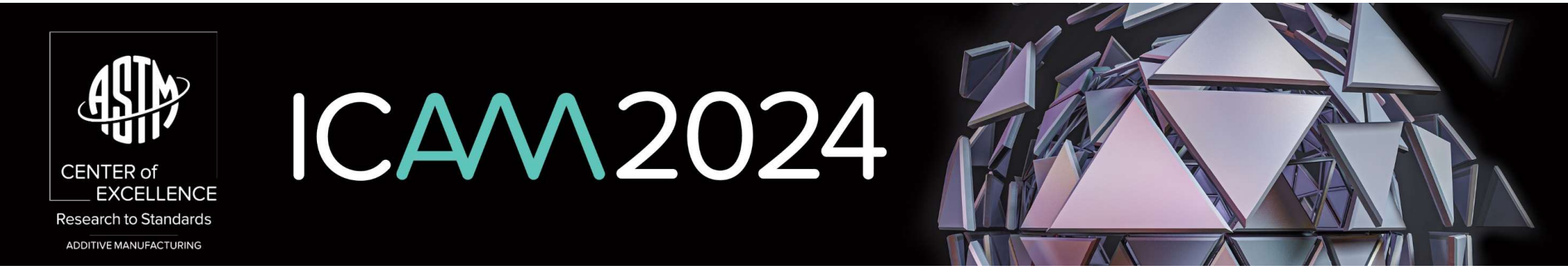
Software UI





Data acquisition and processing architecture





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Thank you.

Bernard Revaz

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