



Additive Manufacturing revolution in the Aeroengine Business



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Organizzato da



GE Aviation in Europe



12,000 Employees
2,500 Engineers

Engineering centers
Production plants
Testing facilities
Repair & Overhaul centers



Our Technology & Innovation model ... meeting stakeholder needs

Stakeholder needs



- Asset availability
- Efficiency / eco-friendly
- Predictability
- Reduced inspection burden

Technology innovation



- Hybrid Electric
- Additive Manufacturing
- Digital Analytics
- Advanced Materials
- Cooling & Aerodynamics
- Architectures

**Reliable,
economical,
sustainable
products**



Hybrid Electric



Additive Mfg



Digital Analytics



Opportunity

GE Aviation... The Additive Advantage

1 Expands What is Possible ... opens up new engineering capability to optimize part & system designs in a way we cannot with traditional manufacturing processes

2 Improves Quality ... eliminates design trade offs; reduced defect opportunities, digital v. analog control, reduced anomaly size and frequency v. traditional castings

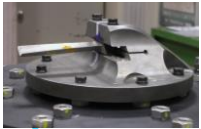
3 Simplifies Our Engines ... more robust designs, reduced part counts, reduced braze/weld/rivet/bolted joints and assemblies; optimized systems



GE Aviation History in Brief

Technology

Start of development on additive TiAl @ Avio Aero



First LEAP Fuel Nozzle



1° Heat Exchanger



PW 800 AOS Certified (Avio)



GE90 engine T25 Sensor Certified



LEAP Fuel Nozzle Certified



Oil & Gas Nova LT Swirler



Demo A-CT7 Engine



GE9X EBM TiAl Blades



Advanced Turboprop Prelim design



Bigger Parts
Bigger Systems
Multi Modalities

2007

2010

2011

2012

2013

2014

2015

2016

2017

Formation of GE Aviation Additive Team

Acquisition of Morris Technologies



GE Aviation Additive Technology Center (ATC) opens



GE's Center for Additive Technology Advancement (CATA) opens



TAL opens



Acquisition of Concept Laser GmbH (75%) and Arcam AB (76%)

CONCEPTLASER
a GE Additive company

Arcam
A GE Additive Company

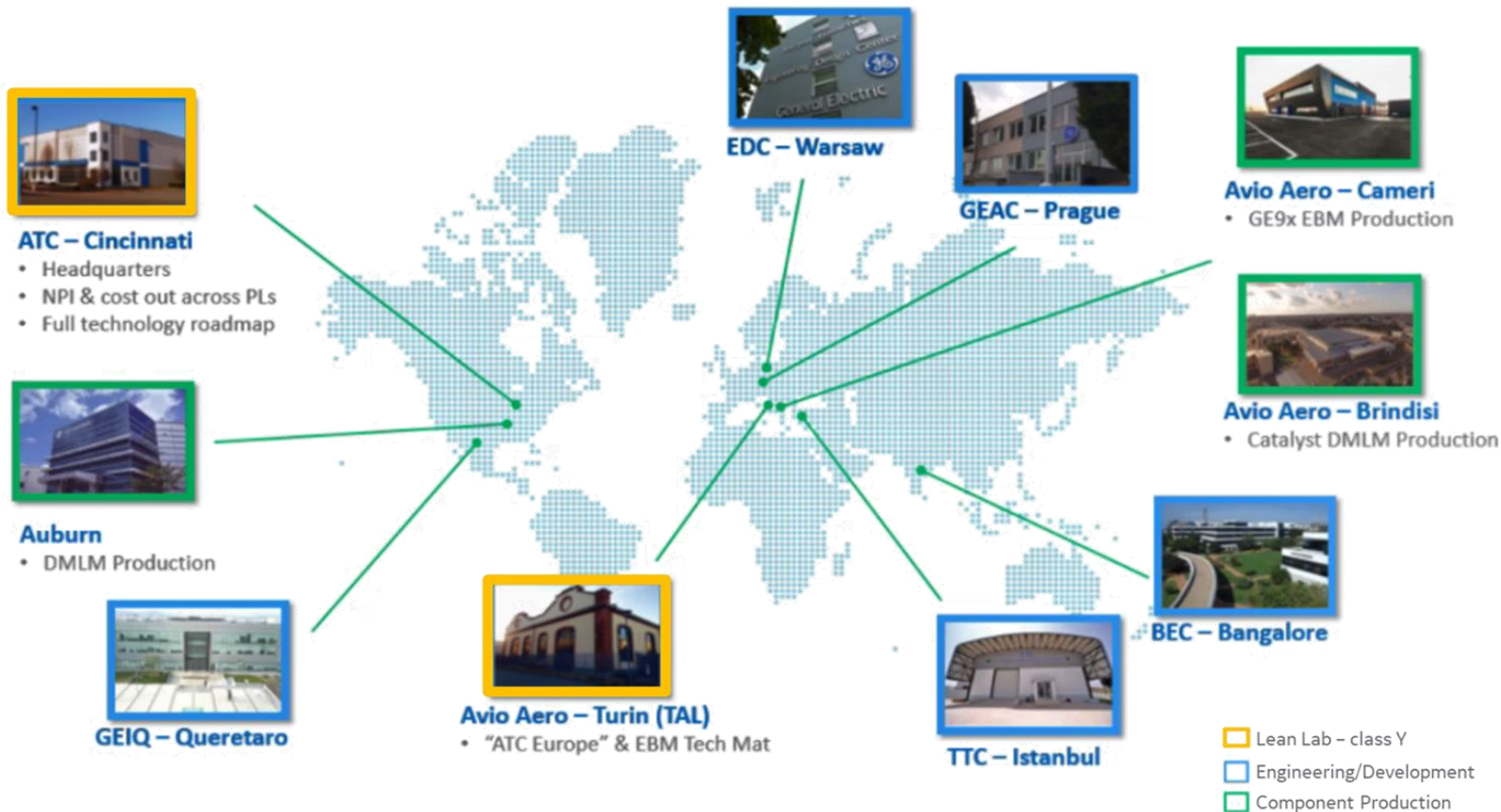
GE Additive Expansion
Customer Experience Center

Infrastructure



Master ASI 4.0 on Additive Manufacturing | May 2019

GE Aviation – Global Additive Footprint



GE: Addressing the Challenges

Understanding the Uncertainty of whole cycle!



Materials



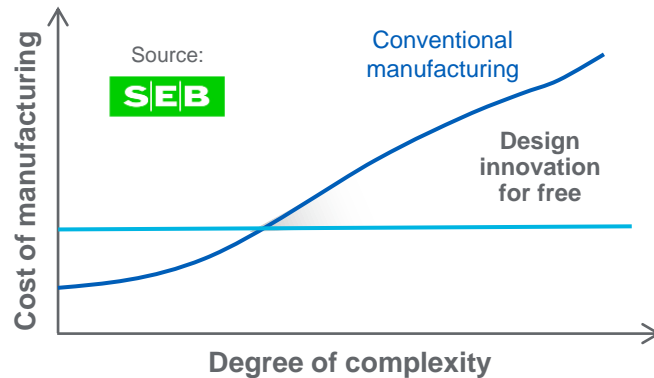
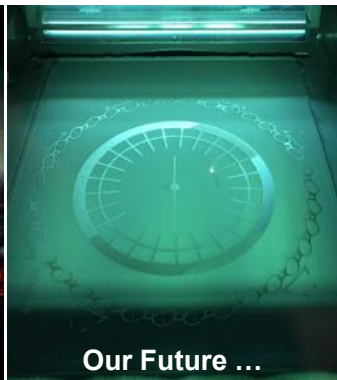
Equipment and Processes



Parts and Products



Additive Manufacturing economics & efficiency



Started at component level ...
LEAP Fuel Nozzle



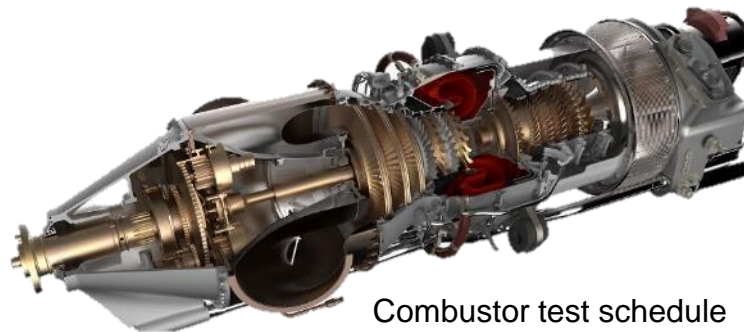
GE9X LPT TiAl blades



**UNIQUE
ALLOY**

...More detail in the follow

... to an Additive system
GE Catalyst - Advanced Turboprop Engine



Combustor test schedule
reduced from **12 months** to **6 months**



LEAP Fuel Nozzle

Capabilities of full production

35,000 – 40,000 per year

25%
PART
WEIGHT
REDUCTION

20:1
PARTS

5x MORE
DURABLE



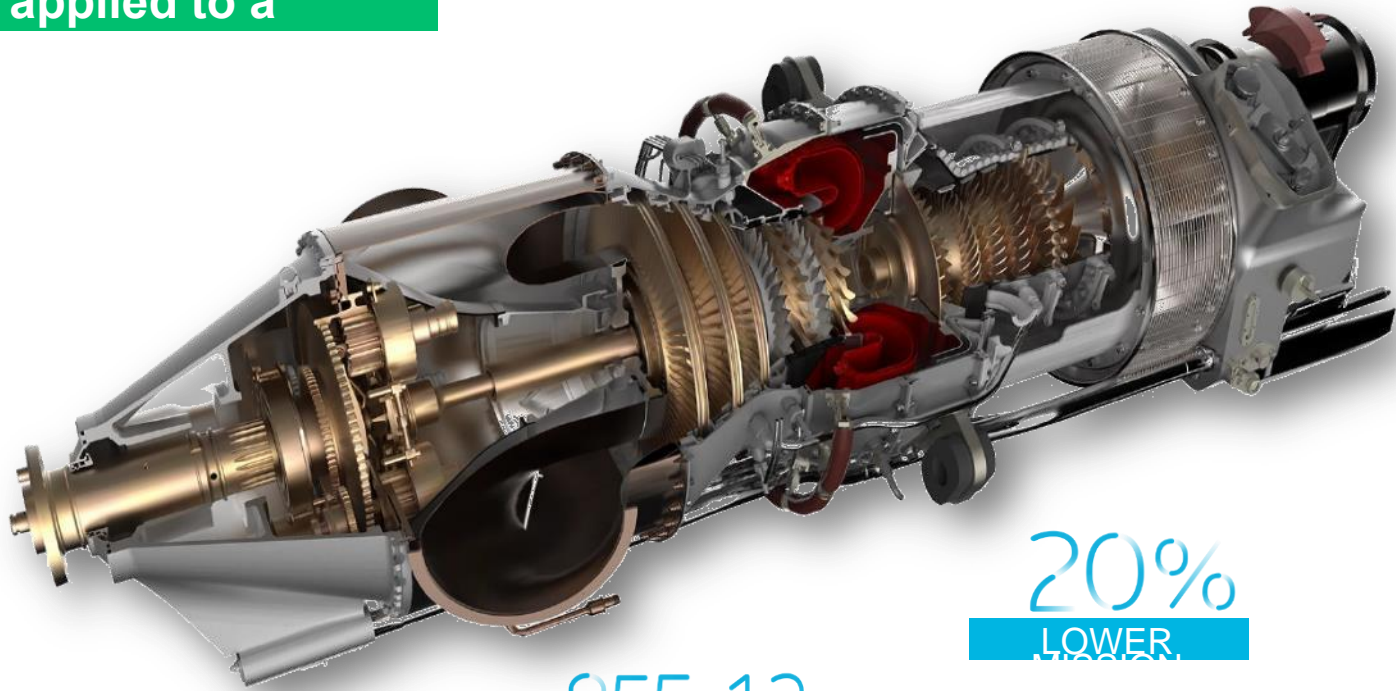
Through September 30, 2018

	FLIGHT HOURS	FLIGHT CYCLES
Engine	2,030,754	909,965



GE Catalyst™ ... advanced turboprop engine

... applied to a



5%
WEIGHT
REDUCTION

20%
LOWER
FUEL BURN

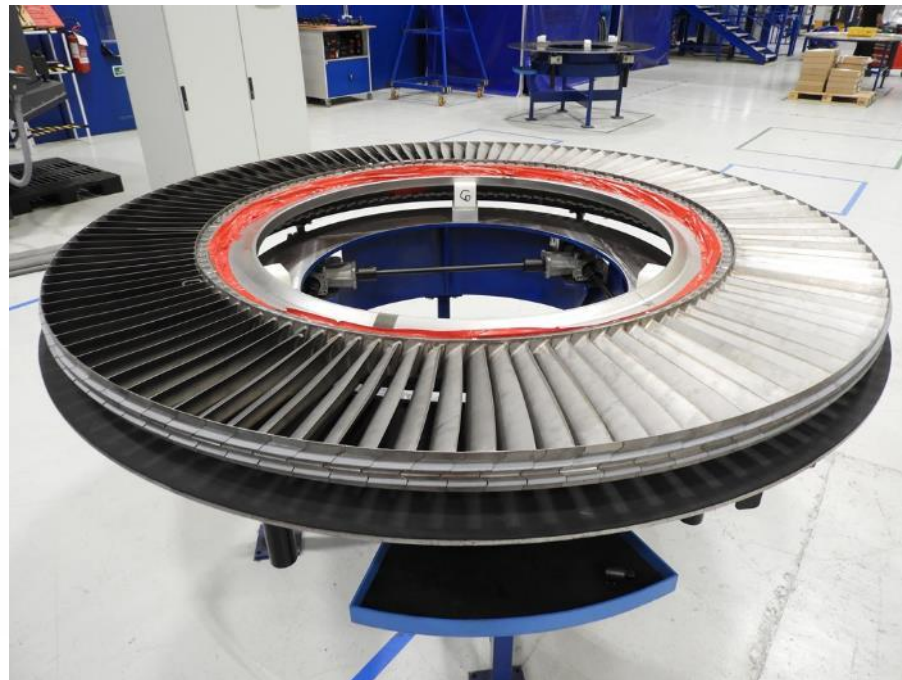
855,12
PARTS



GE9X Low-Pressure Turbine Blades

Unique Alloy

Electron-Beam process



Why TiAl? Why EBM?







GE[®] first engine with **Ti Aluminide** rotor blades: a **~400 lbs saving** per engine

- Ti Aluminide difficult to cast and subject to shrinkage defects
- Only few casting suppliers are able to produce blades

Electron Beam Melting is able to preheat the powder controlling the thermal gradient to avoid shrinkage and cracks defects during production

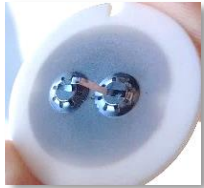
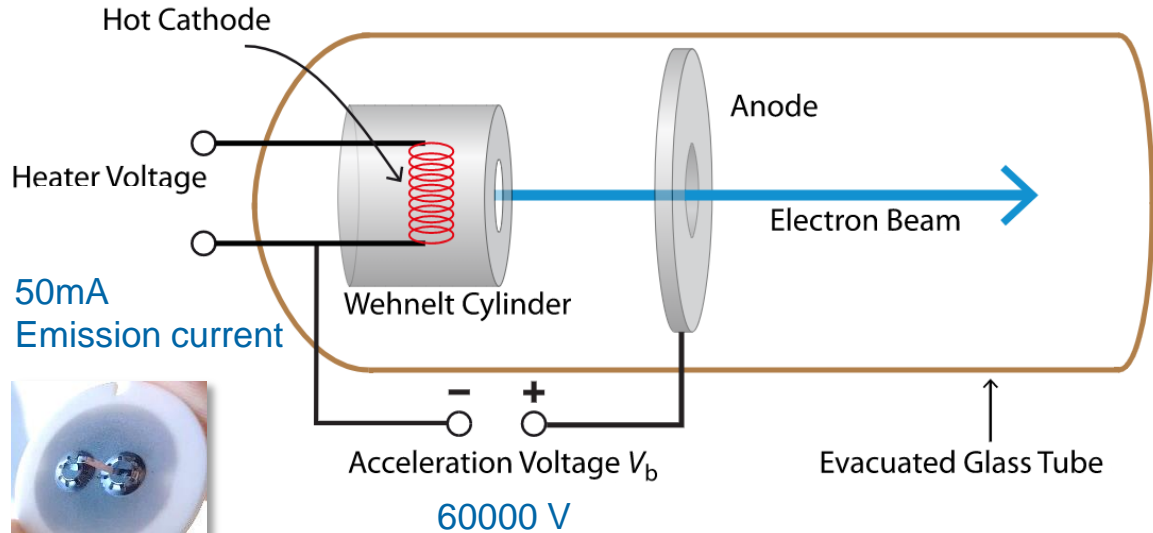


DMLM - EBM Comparison

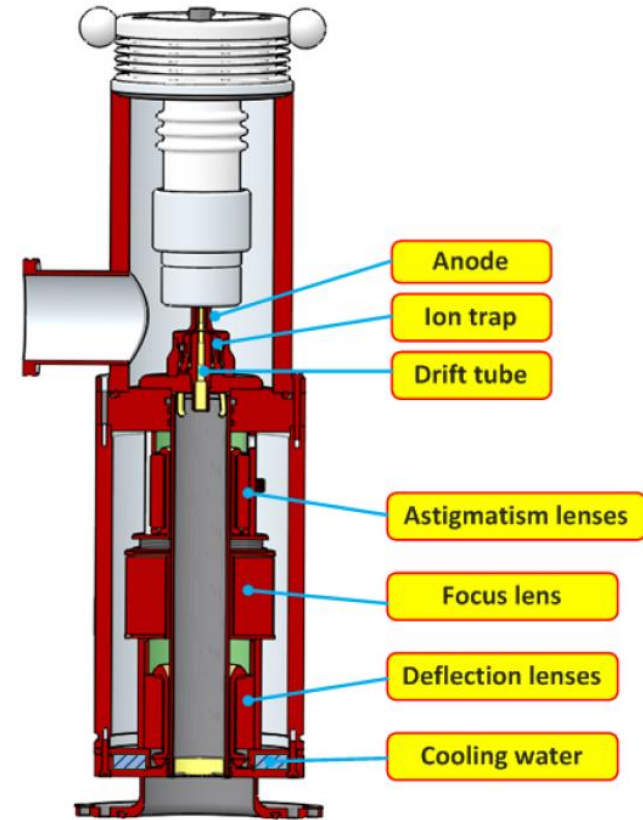
	DMLM Direct Metal Laser Melting 	EBM Electron Beam Melting 
Energy source	<ul style="list-style-type: none"> • 100-1000 W fiber Laser • Scanning with optical mirrors • Scan speed up to 7 m/s 	<ul style="list-style-type: none"> • 3000 W Electron Beam • Scanning with magnetic deflection • Scan speed up to 8000 m/s
Atmosphere	Nitrogen / Argon 	Vacuum 1×10^{-4} mbar partial pressure of He 
Spot size	~100 μm	~180-500 μm
Layer	20-40-50 μm	50-90 μm
Powder bed temp	30-200° C	700-1000° C
Recoater	“Hard” recoater	“Soft” recoater



Electron Beam Gun (EBM)

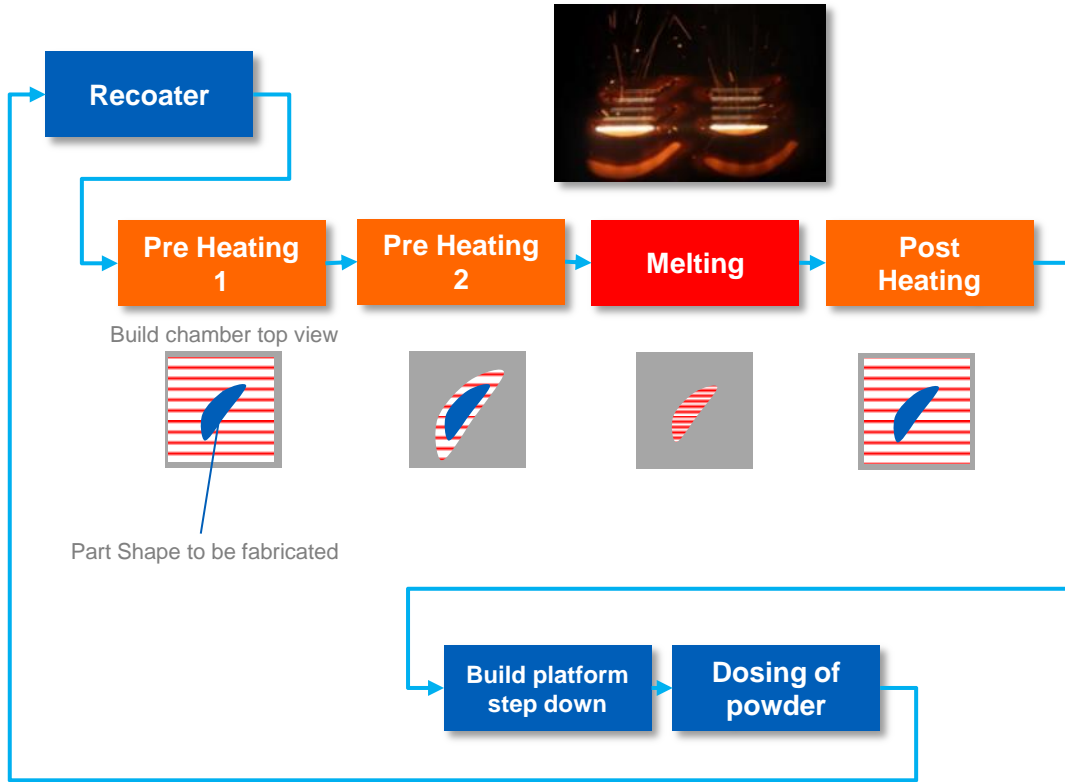


$60000 \times .05 = 3 \text{ KW Beam Power}$

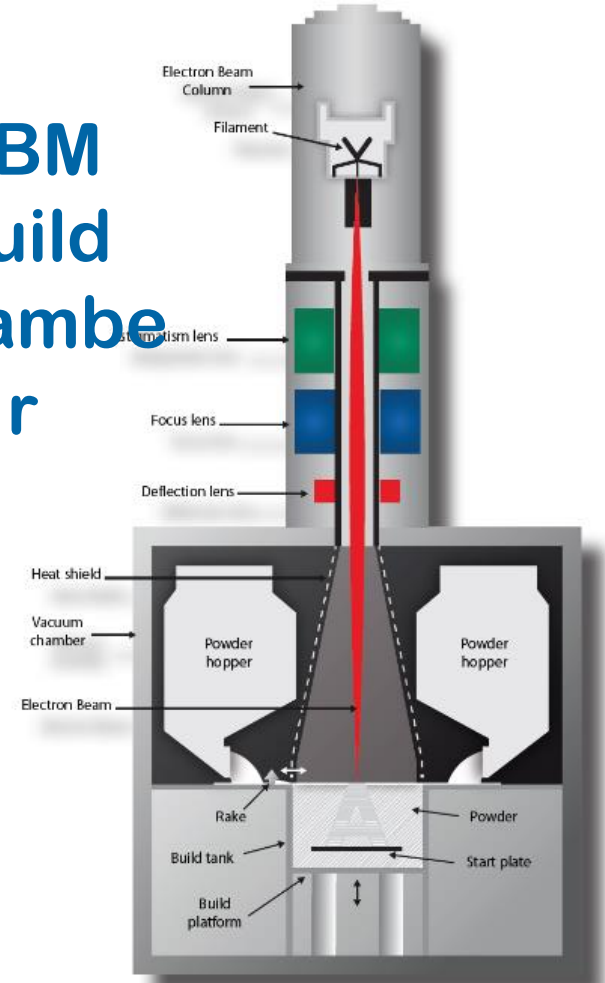


Electrons, unlike photons, have mass and electric charge...

EBM Processing Phases



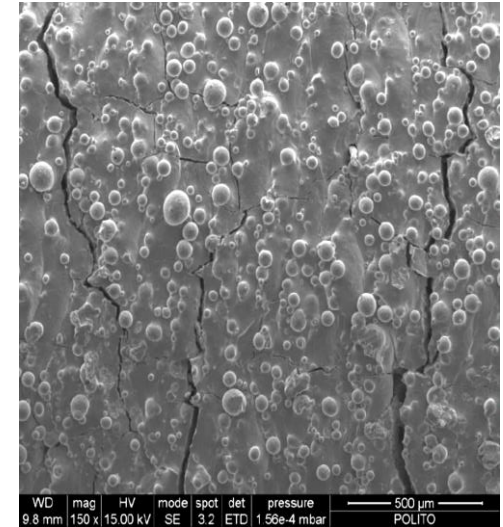
EBM Build Chamber



EBM Characteristics

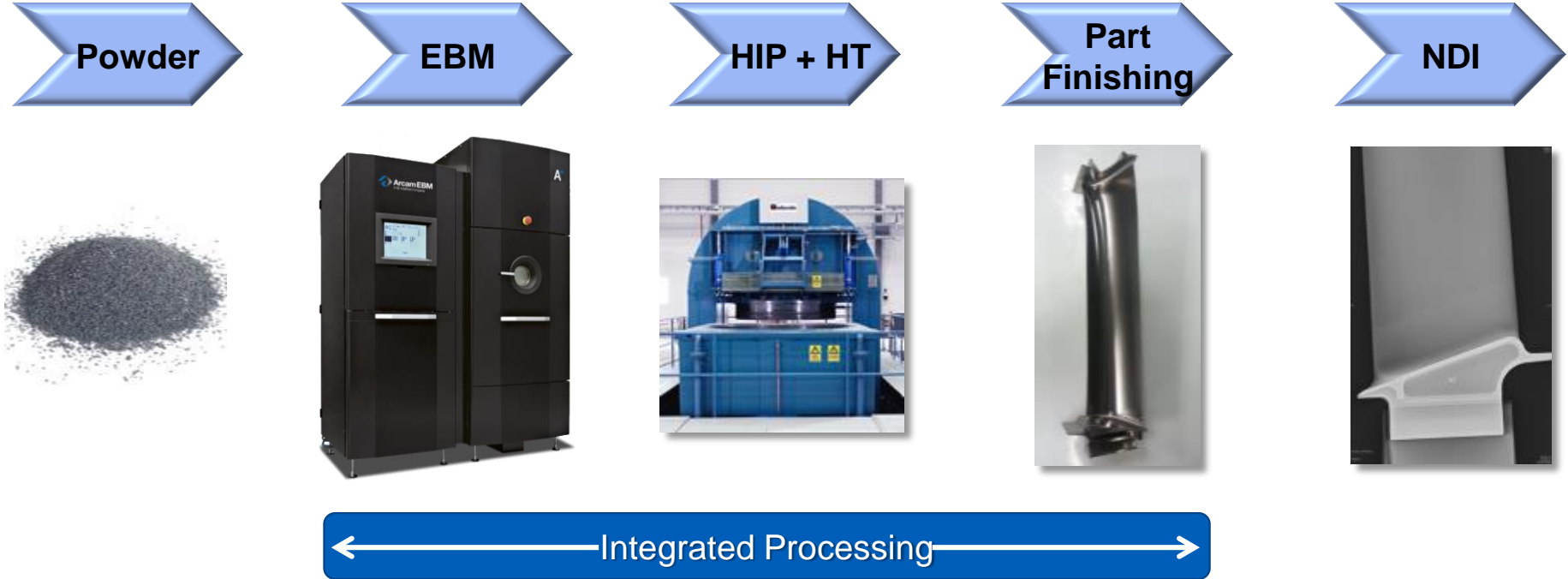
High temperatures – “Low” gradient

- Higher energy absorption compared to laser → higher layer thickness (higher productivity)
- Higher range of powder PSD (up to 100-150 μm)
- Reduced temperature gradient in melt process - Low residual stress
- Allows for production of big bulky parts
- Possible to manufacture materials that are prone to weld cracking at low temperature, e.g. TiAl and advanced super alloys

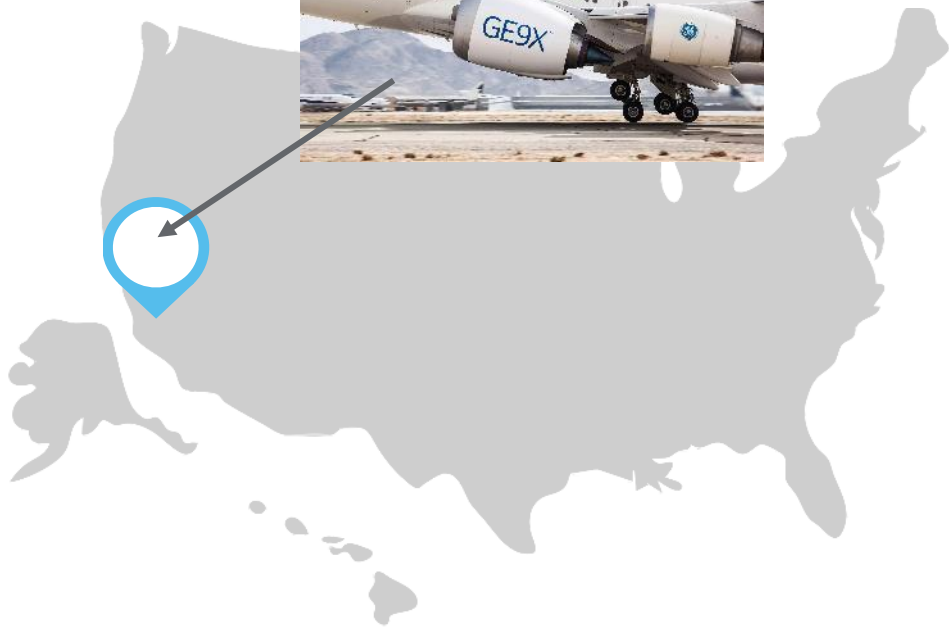


TiAl cracking - **DMLM**

EBM TiAl – Multiple TRL / MRL Maturation Steps Required



GE9X TiAl blade production taking off!



Cameri, Italy
GE Aviation EBМ production site



