Centro Italiano Ricerche Aerospaziali

Applications of EBM technology in aeronautics and space field

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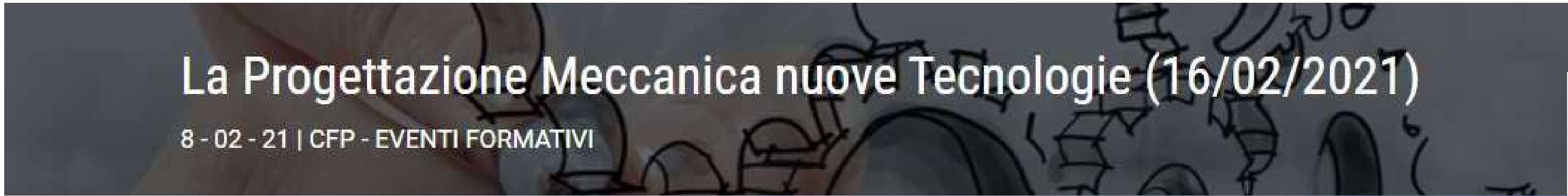
Manufacturing Processes – Metallic Materials



ORDINE DEGLI INGEGNERI DELLA PROVINCIA DI CASERTA

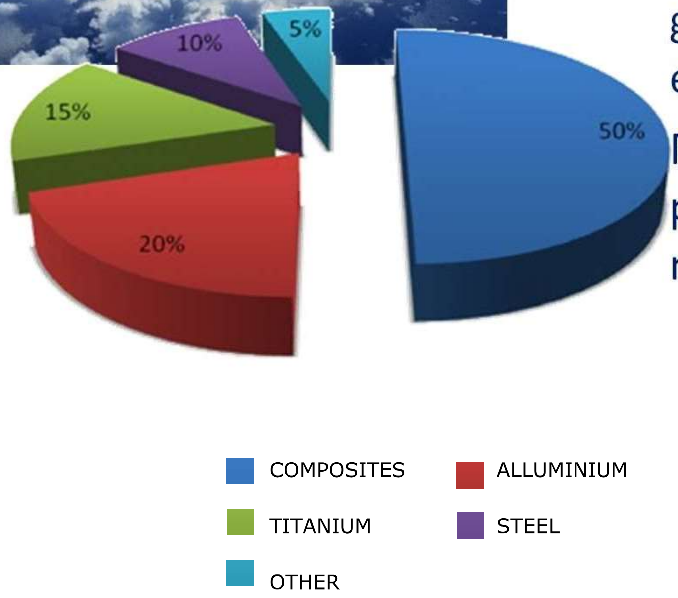
Strategic Objectives

The strategic objective of the "*Manufacturing Processes on Metallic Materials*" is to design, characterize and optimize innovative processes for the manufacturing of structural metallic components for aeronautical and space applications with the final target to reduce the manufacturing costs, time and scraps and obtaining more performant structures.

The laboratory is focused on study and research activities related to
Additive Layer Manufacturing of Titanium alloy
and in particular to the ***EBM technology***

TITANIUM ALLOY

Boeing 787 Dreamliner



In the aerospace field, in recent decades, the use of composite materials has become widespread.

This led to an overall increase in the use of TITANIUM (up to 15% of the total weight of the aircraft), which represents the metallic material that is most likely to be associated with Carbon Fiber Reinforced Plastics (CFRP) to manufacture complex structural components, because it avoids the occurrence of galvanic corrosion and has a coefficient of thermal expansion close to that of CFRP.

More than high cost of raw material, one of the main problems related to the titanium components manufacturing is the low workability.

CASTING

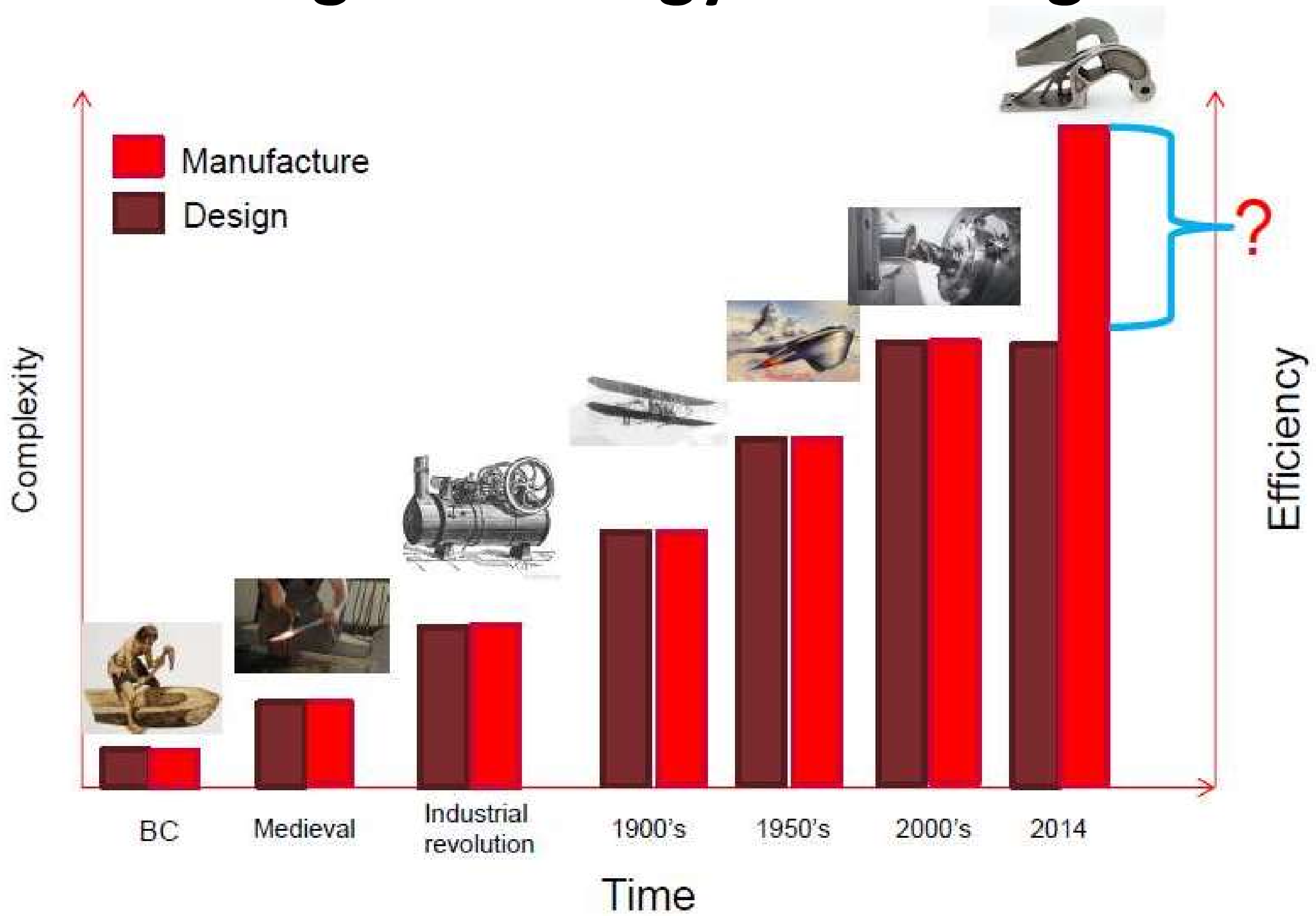
WELDING

PLASTIC FORMING

MACHINING

ADDITIVE MANUFACTURING

Why additive manufacturing?
Manufacturing technology w.r.t design technology



Imagination is the limit

After all, the *geometrical freedom* of additive manufacturing allows you to engineer or design your part as you envision it, without manufacturing constraints.

Topologycal optimization is strategic

THINK ADDITIVE!!!

But there's more…
Additive manufacturing offers important benefits: because of its very high material utilization, additive manufacturing is also an *energy efficient* and more *environmentally friendly* way to go compared to traditional methods.

Low buy to fly ratio (1,5:1)!

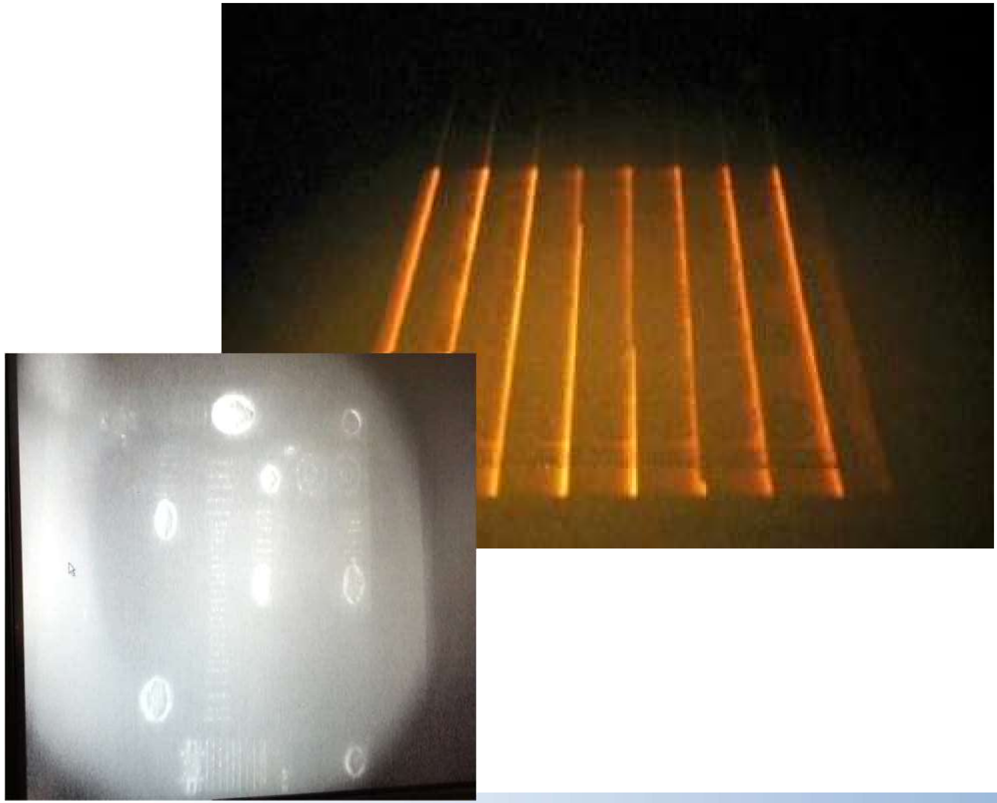
With Additive Manufacturing parts are built by melting thin layers of material, that is added instead of removed (as is the case in traditional machining).
Each layer is melted to the exact geometry defined by a CAD model.
Additive Manufacturing allows for building parts with very complex geometries without tooling, fixtures and without producing any waste material.

- The CIRA ALM Lab is equipped with a “large capacity” of EBM machine (**ARCAM A2X**)
- Actual build envelope: 210 x 210 x 380 mm (W/D/H)
- Power: up to 3.500 W
- Specific Power: 106 kW/cm^2
- Vacuum Process Clean & controlled environment (10^{-4} mBar)
- Hot Process: Designed to process titanium alloys as well as materials that require elevated process temperatures

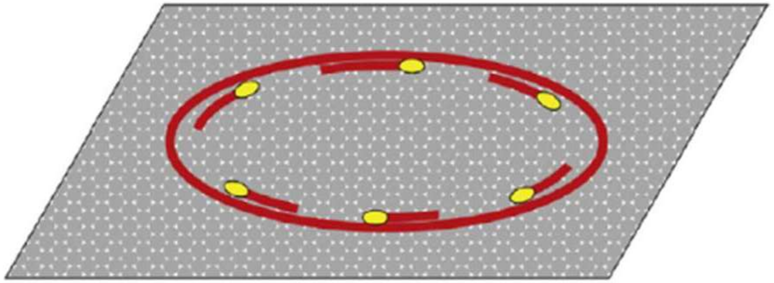
CIRA is equipped with an **ARCAM A2X** EBM System

Each layer to be created typically requires two process themes:

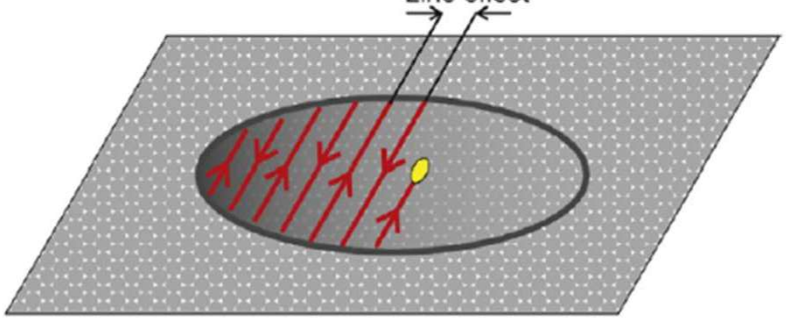
1. Preheating (Low residual stress in the part)
2. Melting (contouring +hatching)



Contouring



Hatching



POWDER RECOVERY SYSTEM (PRS)

- **Remove sintered powder from workpiece;**
- **Recovery powder (95%-98%);**
- **Separate recycling powder from not recycling powder.**

The powder recovery systems include integrated sieving and re-filling of the powder containers which makes it possible to recycle all un-melted powder with a minimum of manual intervention.

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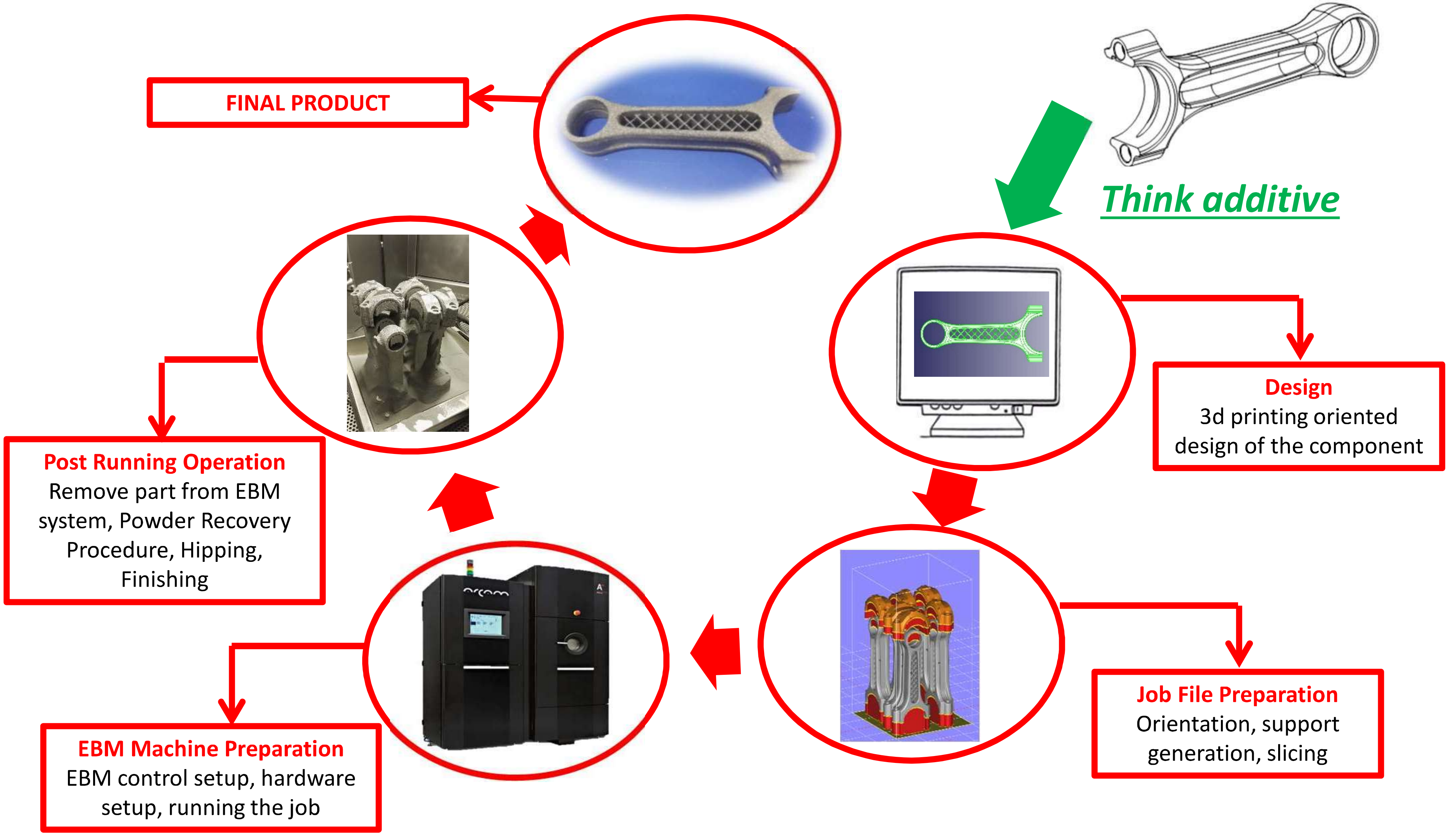
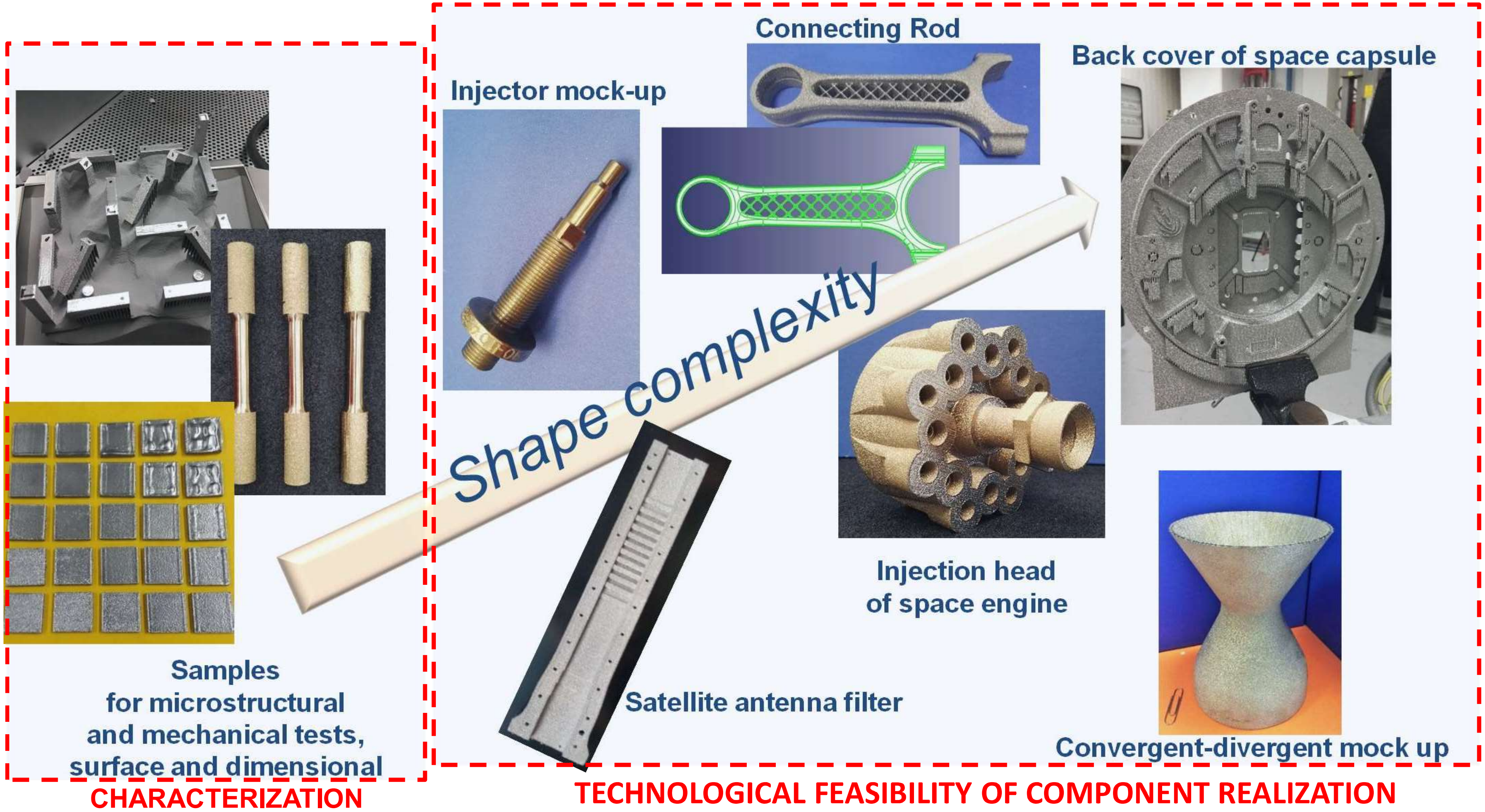
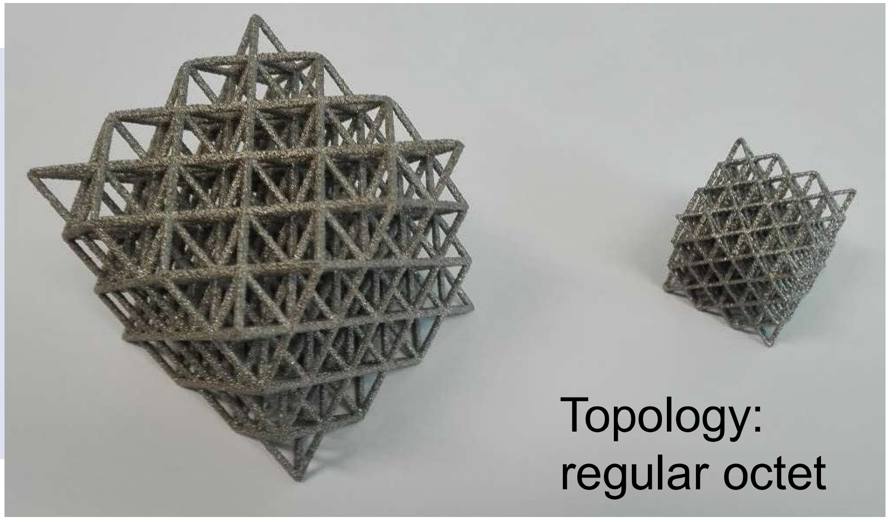
EBM PROCESS: OPERATING PROCEDURE



RESEARCH ROADMAP



Topology optimezed structures are pretty good, but lattice structures could be even better!!!



EBMed lattice structures:

Investigation on the performances of lattice structures manufactured via EBM.

THE TIMA PROJECT

TIMA (Tecnologie Innovative per Motori Aeronautici a combustione interna a basso impatto ambientale ed elevata autonomia) was a **RITAM** project. RITAM (RIcerca su Tecnologie Avanzate per Motori) is a consortium whose partners are CIRA, CSM, CMD, UNINA, UNISA, CRDC

The RITAM-TIMA project has the objective to find innovative design solution for aeronautical engine parts to be manufactured by using the **ALM process**

Example of a Connecting Rod in a step-by-step design innovation process

- ❑ Possibility to obtain optimized geometries by using ALM techniques with reasonable manufacturing costs

❑ Forging

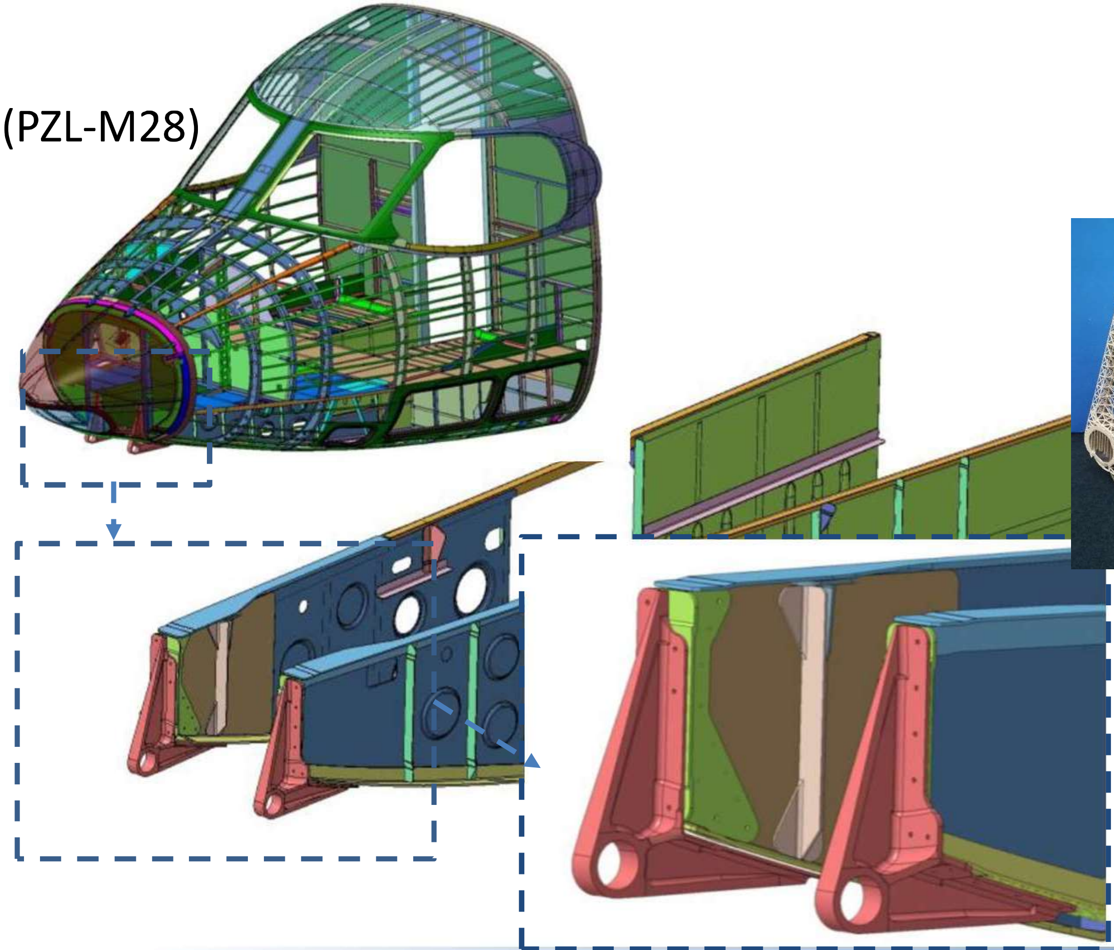
❑ ALM

-12% vol
-50% weight

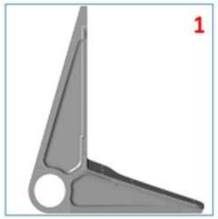
SAT-AM (Smart Aircraft Affordable Manufacturing) is a H2020-CS2 Project

Objective: to develop technologies for manufacturing lighter and cheaper airframes while its reliability is maintained or increased.

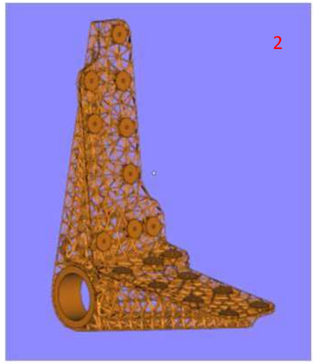
(PZL-M28)



CURRENT DESIGN
in AA (524g)



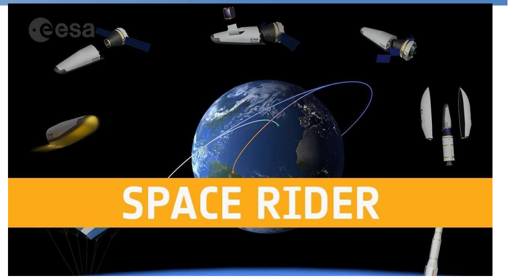
REDESIGN
THINK ADDITIVE
TOPOLOGICAL
OPTIMIZATION



FINAL PRODUCT in
Ti6Al4V (473g)

weight
saving
11%

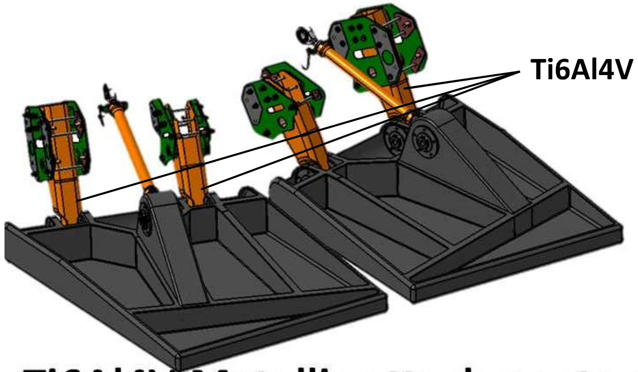
**Re-design and manufacturing
with ALM tech of Fuselage NLG fitting**



The **Space RIDER** (Space **R**eusable **I**ntegrated **D**emonstrator for **E**urope **R**eturn) is planned uncrewed orbital spaceplane aiming to provide the European Space Agency (ESA) with affordable and routine access to space. Its expected maiden flight is 2022.

Development of Space RIDER is being led by the Italian PRIDE programme in collaboration with ESA, and is the continuation of the Intermediate eXperimental Vehicle (IXV) experience, launched on 11 February 2015.

Space Rider aims to provide Europe with an affordable, independent, reusable end-to-end integrated space transportation system for routine access and return from low orbit. It will transport payloads for an array of applications, orbit altitudes and inclinations.



CIRA is presently in charge of the design, manufacturing and qualification of the Body Flaps Assembly of the Space Rider Re-entry Module.

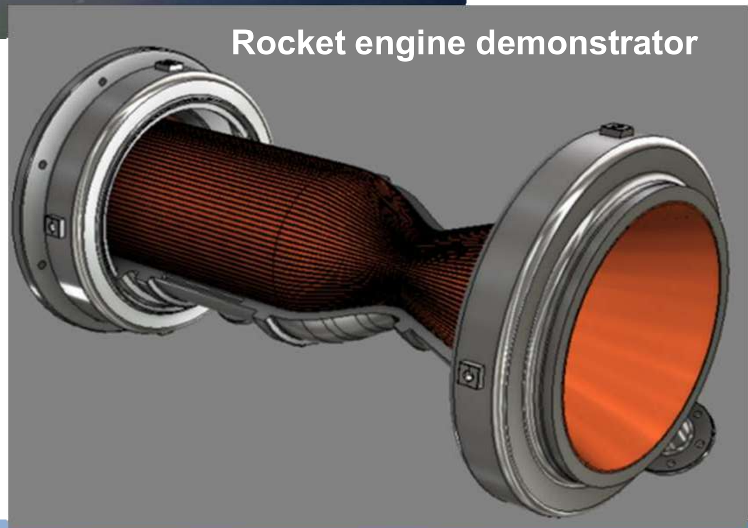
Ti6Al4V Metallic attachments of C/SiC Body Flaps with cold structure have been realized for full scale development model with the EBM machine, available at CIRA, reducing time and cost for manufacturing.

Qualification of process for Space Rider application is on going.

THE HYPROB PROJECT

The **HYPROB Project** is funded by **MUR** through the National Aerospace Research Program (**PRORA**).

OBJECTIVE
Design, manufacture and testing of ground demonstrator (**L0X/LCH4 engines**) for spatial propulsion system.


Rocket engine demonstrator

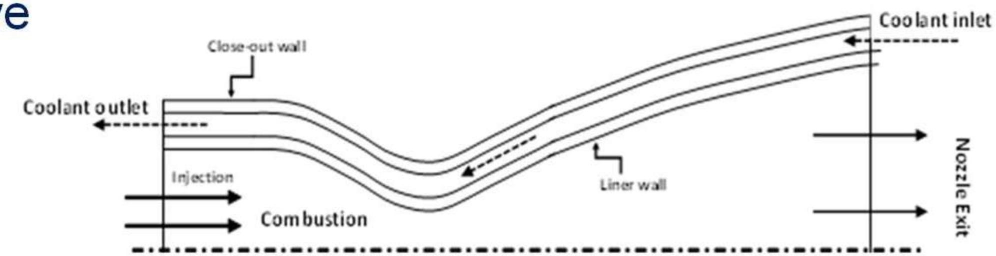
The thrust chamber is the part where the propellants are mixed, burned and accelerated to generate thrust.

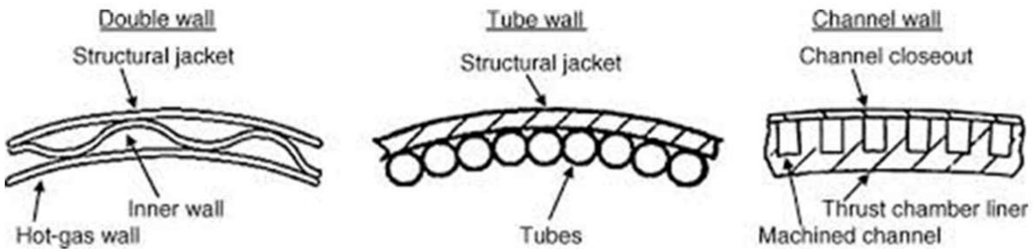
THE HYPROB PROJECT

CIRA CHALLANGE

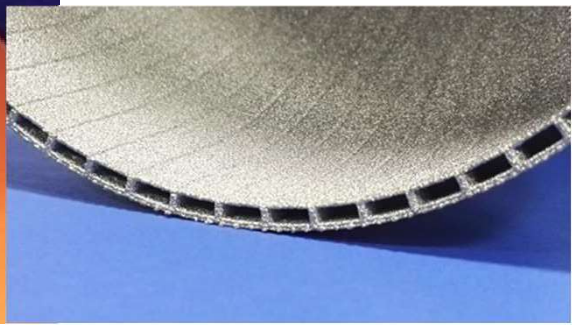
Manufacturing of the whole **Regenerative cooled thrust chamber** in Ti6Al4V with a monomaterial and monolithic innovative design (no need for brazing)

Combustion chamber typical section





Convergent-divergent mock up



Design | Materials | Machine | Post Processing

AM allows to put material directly in the right place instead of removing it only where possible!

Think additive

Optimization topology
- Weight saving
- Improving performances
- Reducing post processing

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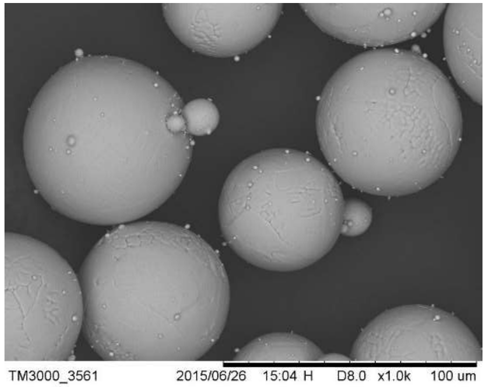
TECHNOLOGICAL CHALLENGES

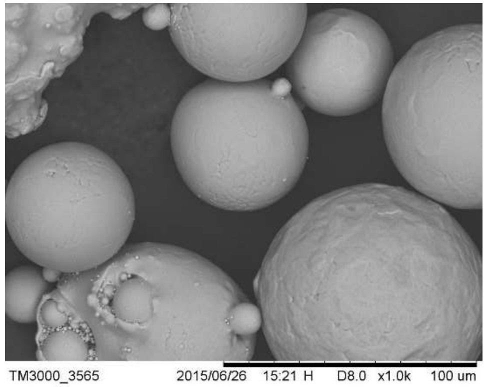
Design → **Materials** → Machine → Post Processing

- Producing machine independent metallic powder in order to reduce feedstock costs.
- Orienting the powder metallurgy to optimize the final properties of the alloys used, studying and qualifying new powders ad hoc developed for AM technologies.
- Virgin vs. Recycled

VIRGIN POWDER - 1000X



RECYCLED POWDER - 1000X



Courtesy of DICMAPI UNINA

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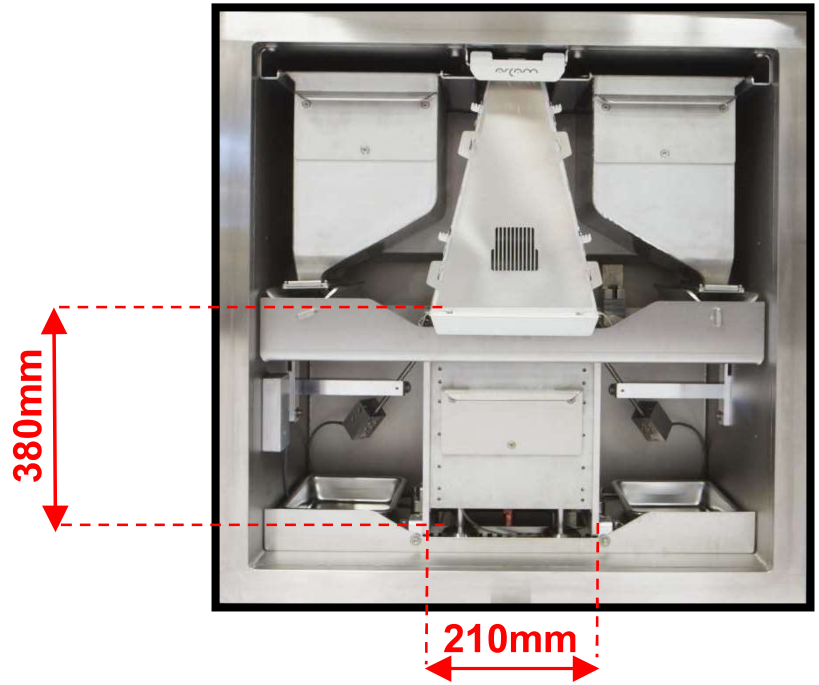
Design | Materials | **Machine** | Post Processing

The maximum **dimensions of printable AM components** produced by Powder Bed Technologies are nowadays limited due to the very small build envelope of modern machine.

Machine with **larger build envelope** need to be designed



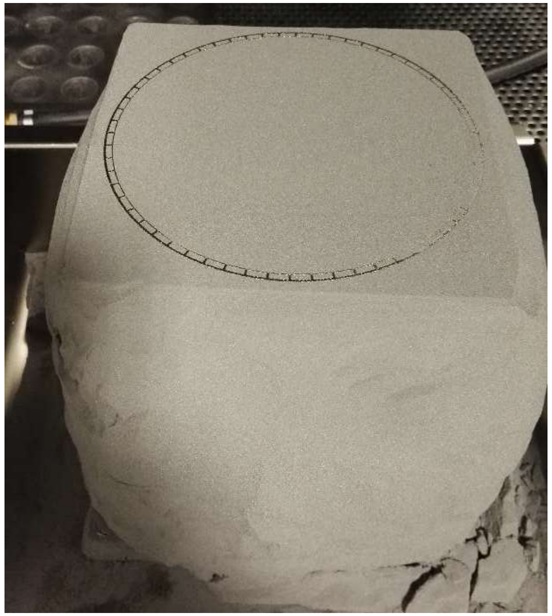
Design | Materials | Machine | **Post Processing**

The maximum dimensions of printable AM components produced by Powder Bed Technologies are nowadays limited due to the very small build envelope of modern machine.

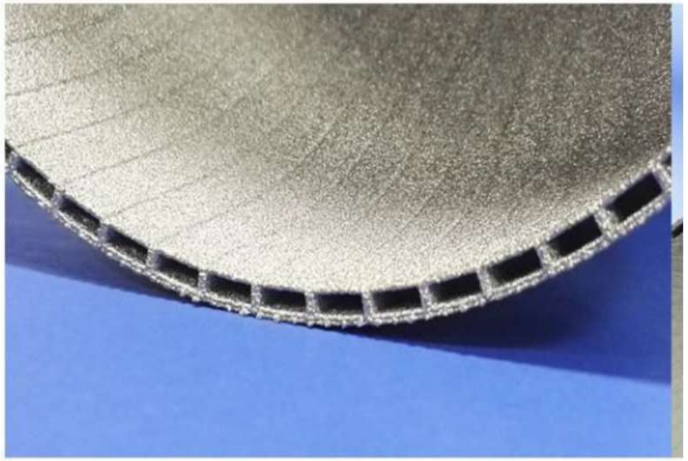
Joining techniques need to be assessed and/or developed

LFW

Design | Materials | Machine | **Post Processing**



Rigenerative cooling of liquid rocket engine thrust chamber with N.60 channels (section 2.1 x 5.1 mm)



DEPOWDERING

Among the various industrial cleaning technologies reported in literature e.g., abrasive cleaning, solvent cleaning, brushing, heat cleaning, immersion cleaning, laser ablation, high pressure spray, super critical fluid cleaning and **ultrasonic cleaning**, the last was emerged as very promising for EBM application.

Design | Materials | Machine | **Post Processing**

Precision engineered parts leave no room for error when it comes to surface treatment. A good finishing state allows to:

- Increasing resistance to corrosion
- Reducing friction
- Increasing resistance to wear
- Improving aerodynamics

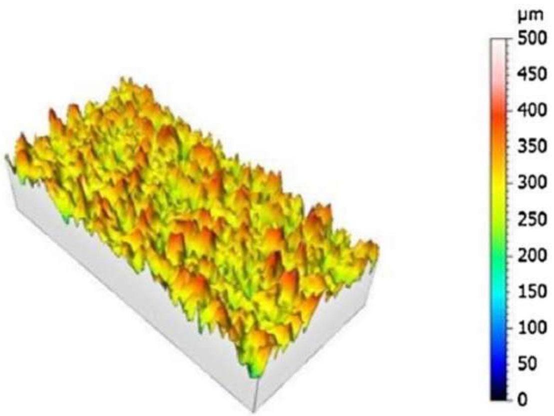
Nowaday machining provides the best results in terms of dimensional accuracy and surface roughness. BUT IT IS NOT STRATEGIC!!!

As EBM processed

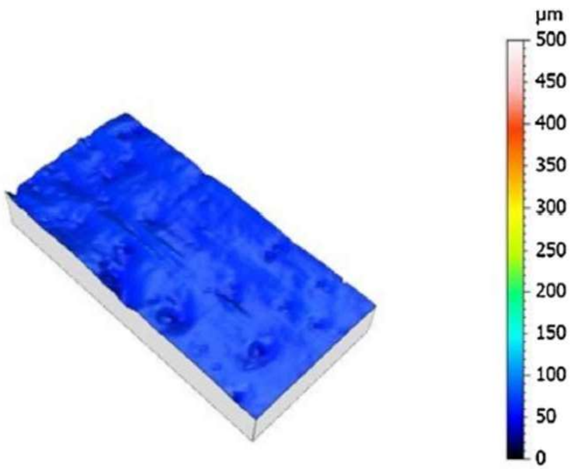
INNOVATIVE SURFACE FINISHING AND POWDER REMOVING TECHNIQUES ARE NEEDED

Design | Materials | Machine | **Post Processing**

Chemical surface finishing



As built surface



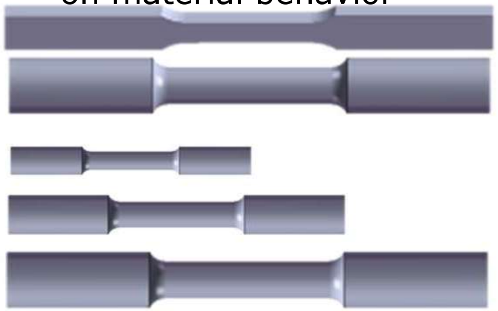
Treated surface

Scherillo F., Manco E., El Hassanin A., Franchitti S., Pirozzi C., Borrelli R., Chemical surface finishing of electron beam melted Ti6Al4V using HF-HNO3 solutions, Journal of Manufacturing Processes, Volume 60, 2020, Pages 400-409, https://doi.org/10.1016/j.jmapro.2020.10.033

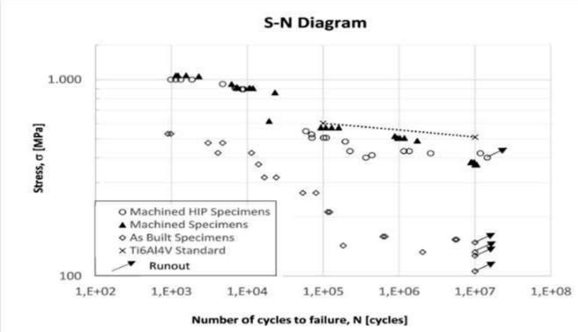
WHAT'S NEXT?

Effect of the temperature on material behavior

Effect of the shape and the size on material behavior

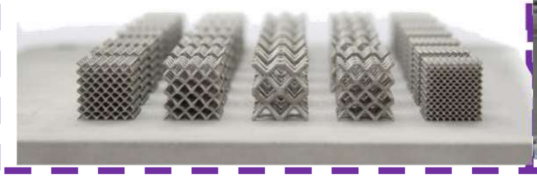


Recycled Powder vs. Virgin powder



New materials…

New Structures…



…and much more!

Qualification of process for space and aeronautics applications!

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