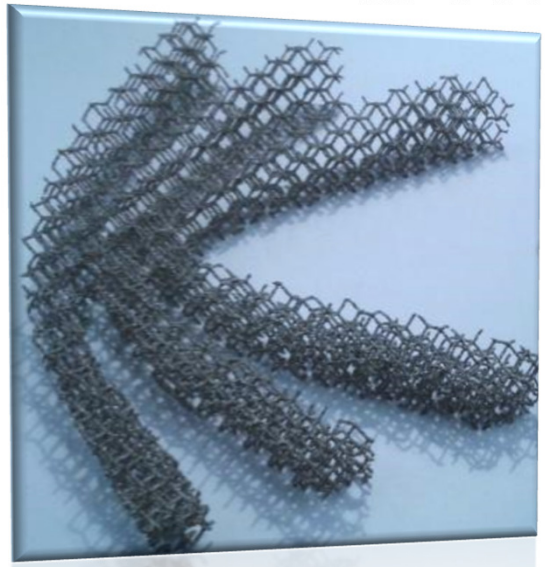
Centro Italiano Ricerche Aerospaziali

# Le attività di Additive Layer Manufacturing al Centro Italiano di Ricerche Aerospaziali




***Stefania FRANCHITTI***

*Laboratorio Processi Produttivi - Materiali Metallici*

*Dipartimento di Strutture e Materiali*

**In 1989, the Italian Government entrusted CIRA the management of the Italian Aerospace Research Program (PRORA). CIRA performs PRORA management under the control of Ministry of Research (MIUR).**

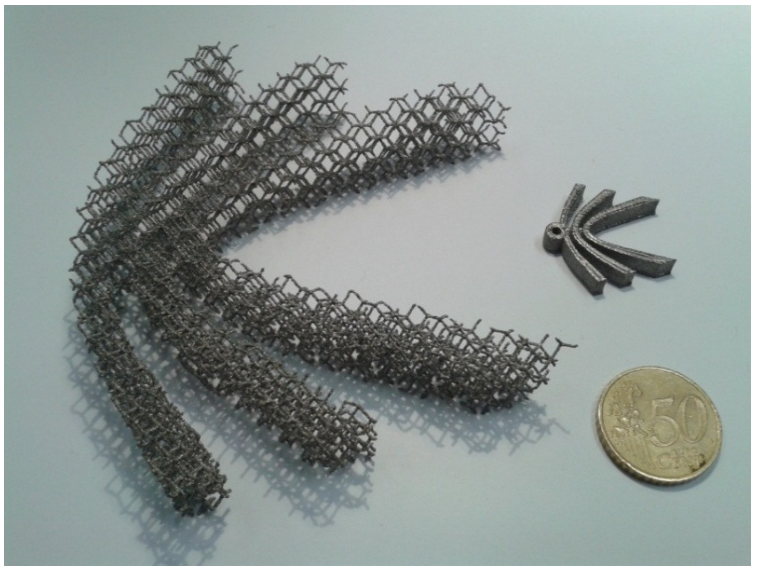
A non-profit public-private partnership among:

- ASI (Italian Space Agency) - 47%
- CNR (National Council for Research) - 5%
- Campania Region - 16%
- Italian Aerospace Industries - 32%

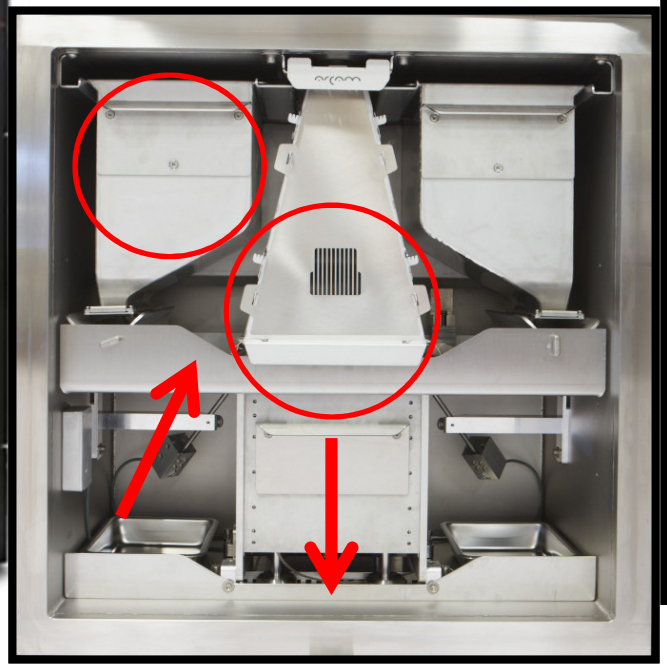

370 employees
and approx. 50 university students and PhD candidates a year

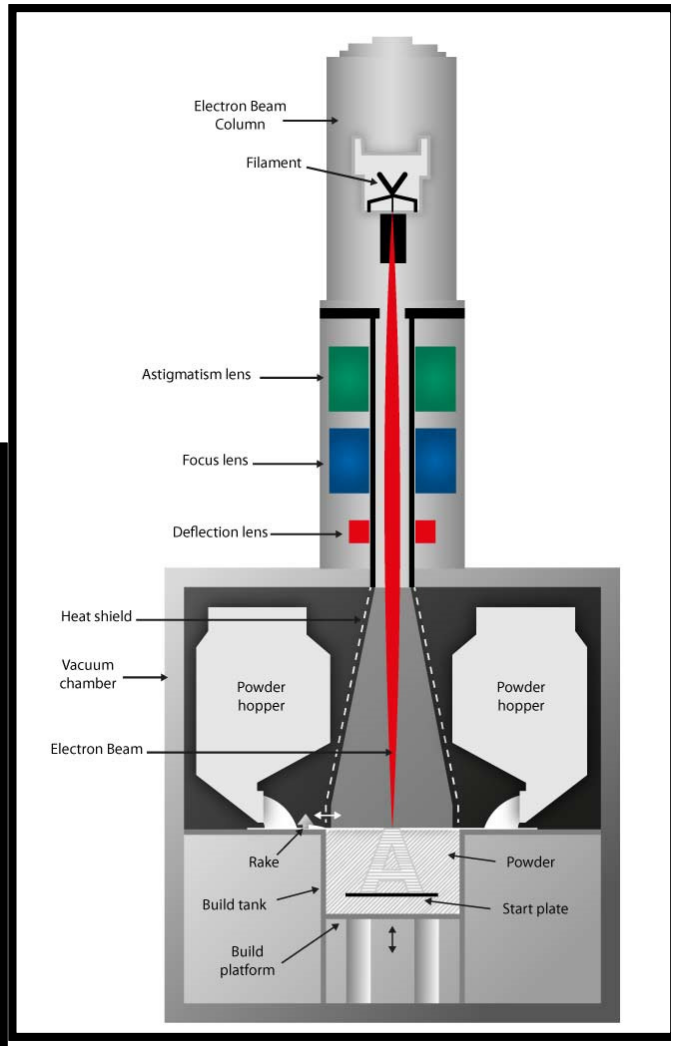
The laboratory is focused on study and research activities related to **Additive Layer Manufacturing** and in particular to the **EBM technology**

- **The EBM technology** has the ability to build dense parts with similar or better properties to any wrought method. The wide range of power spectrum of an electron beam, in principle, makes possible to melt every metal irrespective of the melting temperature.
- In the EBM systems **the high vacuum** in the build chamber provides oxygen free environment ensuring material purity in the part and precise geometry.
- EBM is a green manufacturing process thanks to re-use of excess powder.



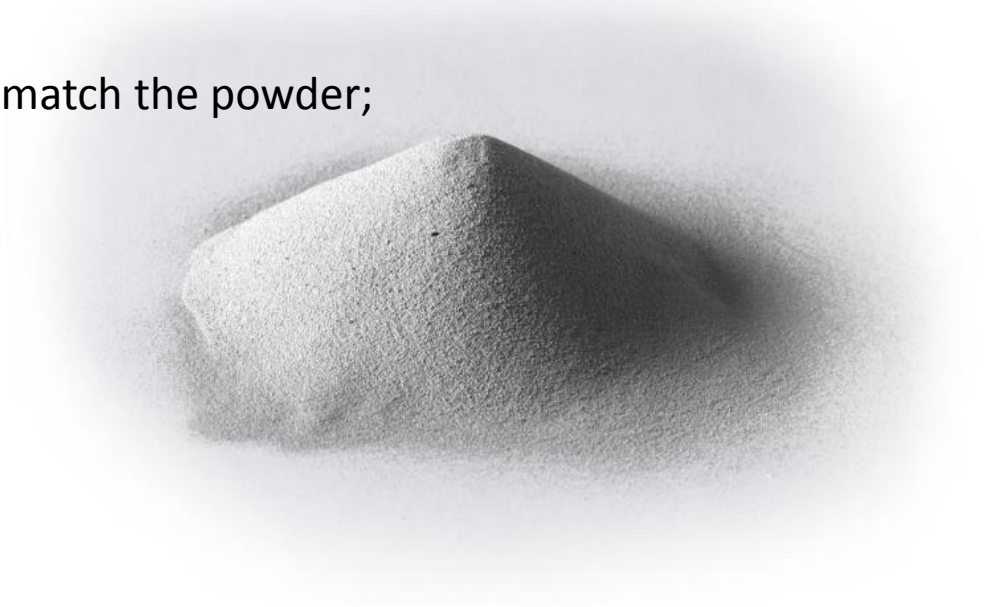
- The CIRA ALM Lab is equipped with a “large capacity” EBM machine (**ARCAM A2X**)
- Actual build envelope: 210 x 210 x 380 mm (W/D/H)
- Power: up to 3.500 W
- Power density: 106kW/cm$^2$
- Vacuum Process Clean & controlled environment ($10^{-4}$ mBar)
- Hot Process: Designed to process titanium alloys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





**Arcam**

- has developed the process parameters that match the powder;
- has qualified and verified the material;
- has guarantees the powder quality;
- has established a validated supply chain.



| |
|---|
| Titanium Grade 5 **Ti6Al4V** |
| Titanium Grade 23 **Ti6Al4V ELI** |
| Titanium Grade 2 **Pure Titanium** |
| Cobalt-Chromium **(ASTM F75) - CoCr** |

Recently Arcam launched a **Nickel Base Superalloy** process for Additive Manufacturing with Arcam's EBM systems. The **Inconel** process is initially available for the Arcam A2X platform (the same as that of CIRA ALM Lab).

**BUT THERE ARE MANY INITIATIVES AROUND THE WORLD AIMING AT NEW MATERIALS**

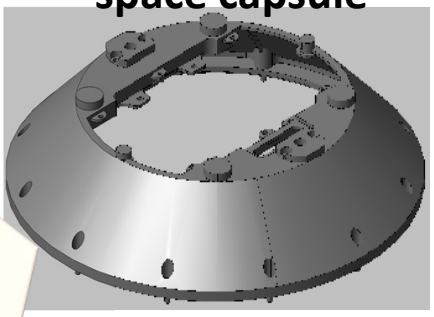
# CIRA KNOW-HOW DEVELOPMENT IS DEVOTED TO

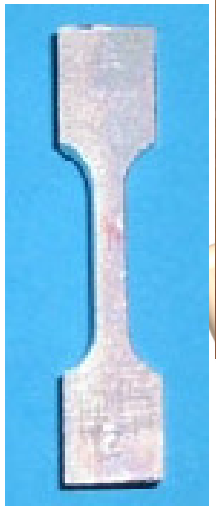
- Developing new design methods ALM oriented.
- Orienting the powder metallurgy to optimize the final properties of the alloys used.
- Acquiring production capability able to support the phases of development of new products (small series production) .
- Identifying post-processing techniques aimed at improving the mechanical and / or geometric features.
- Developing technological and methodological expertise to design, manufacture and characterize complex components in superior metal alloys ALM manufactured.

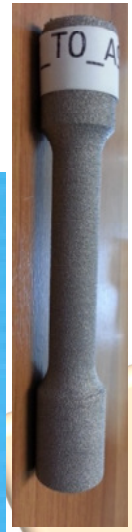
Injector mock-up

Connecting Rod

Back cover of space capsule



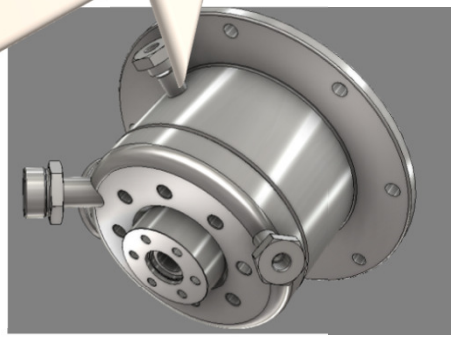




Shape complexity

Samples for microstructural and mechanical tests, surface and dimensional characterization.

Satellite antenna filter



Back plate assembly of the injection head of space engine

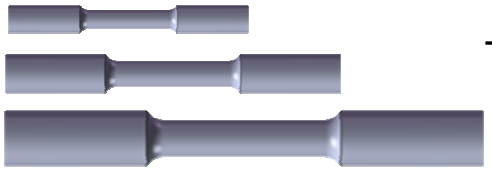
The first step is to perform an **extensive test campaign at a sample level** aimed at:

- **Assessing static mechanical properties (tensile tests) for different growing directions, different geometries (shape and dimension), different temperatures and slicing parameters and with different types of surface finishing.**

**Effect of the "skin-microstructure"**

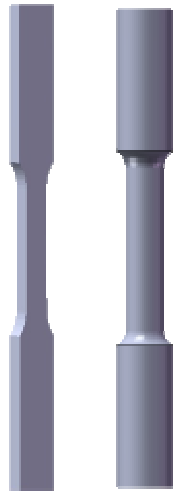
**Influence of Temperature**

Test campaign at room temperature
Test campaign at 190°C
Test campaign at -150°C

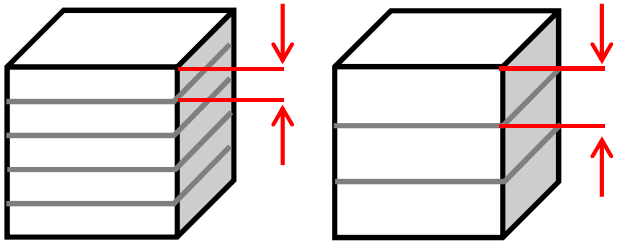


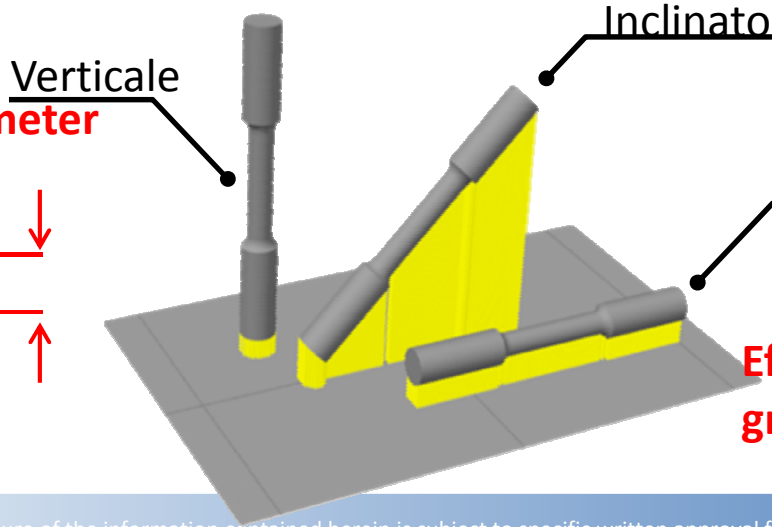
**Material behavior as function of dimensional features**

**Material behavior vs. shape features**



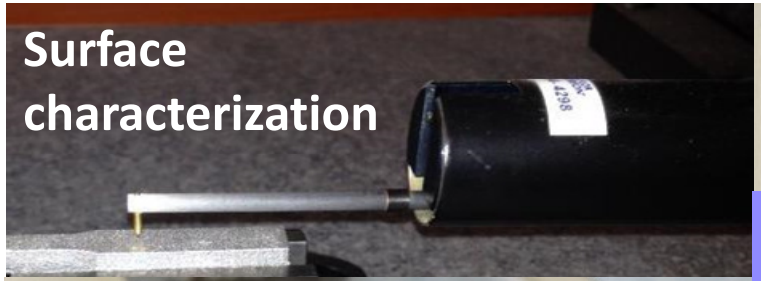
**Influence of the slicing parameter**

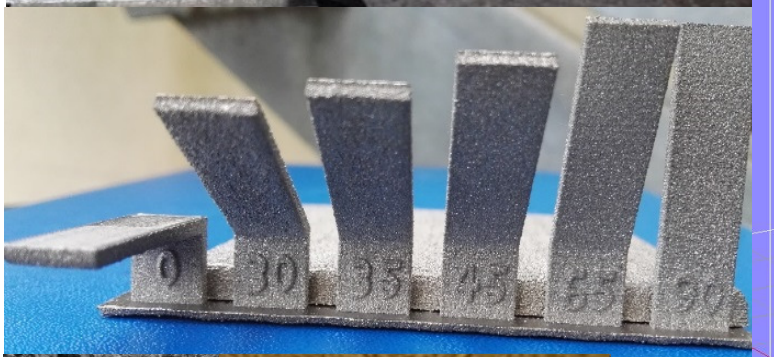


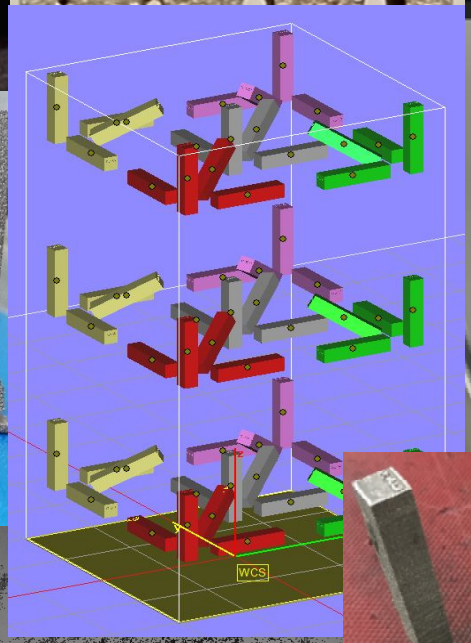


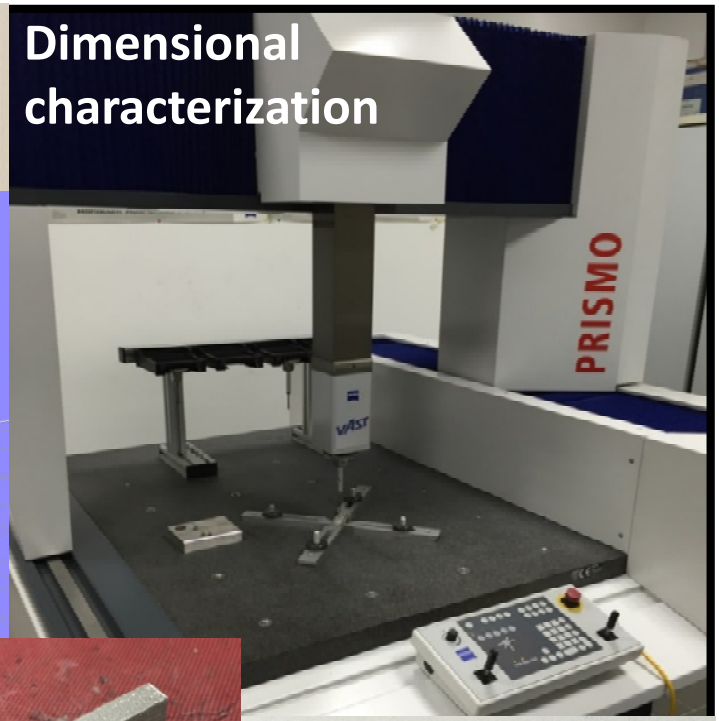

**Effect of growing direction**

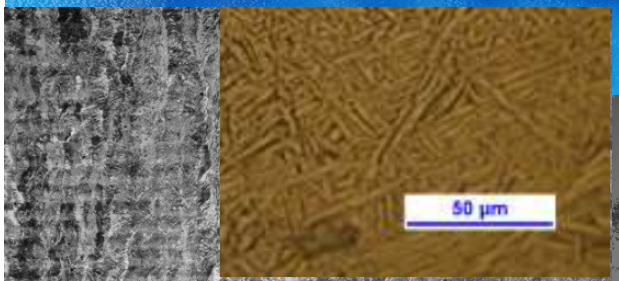
- Assessing possible manufacturing defects, anisotropy and inhomogeneity.



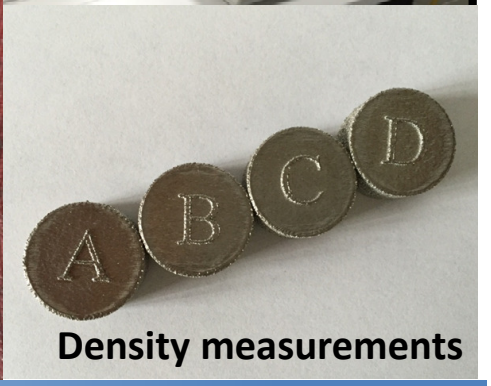


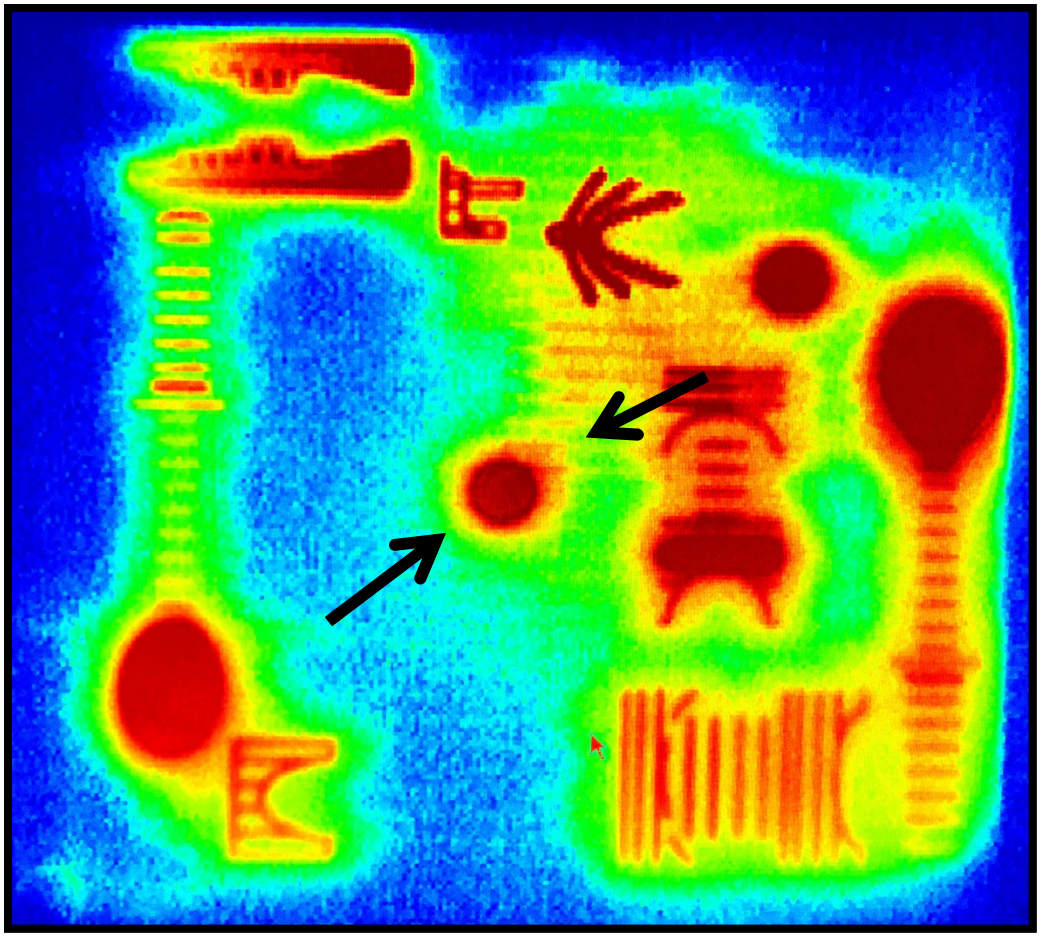











In order to improve the roughness of the components produced by EBM technology, the following surface finishing treatments have been investigated:

- Blasting
- Tumbling
- Fluid Bed
- Machining


**OTHERS ???**

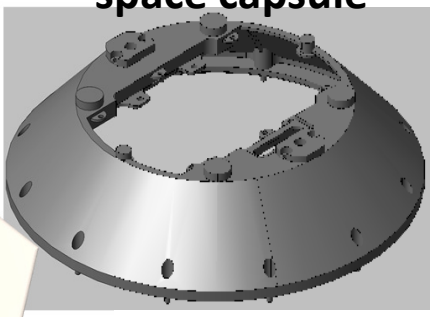
- **Electrochemical machining (ECM)**
- **Electrical discharge machining (EDM)**
- **Peening**

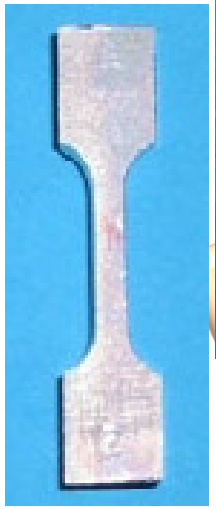
BUT IT IS NOT STRATEGIC!!!

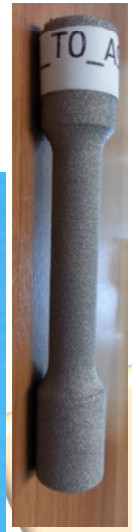
Injector mock-up

Connecting Rod

Back cover of space capsule







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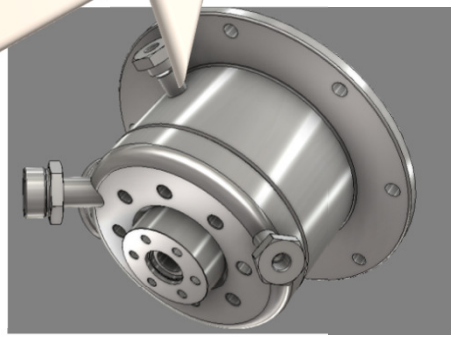
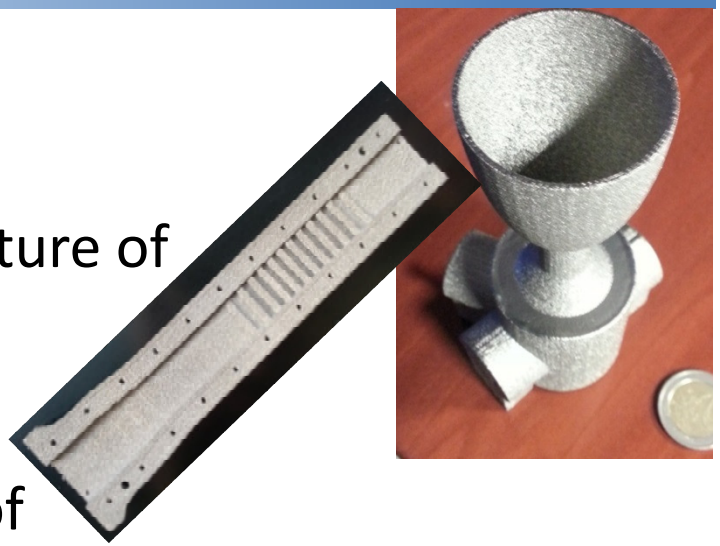


Back plate assembly of the injection head of space engine

## ❑ HYPROB Project

- ✓ The HPRB-TECH Project
  Space Propulsion: Design and manufacture of injection systems for hybrid engines



## ❑ RITAM-TIMA Project

Aircraft Engines: Design and manufacture of connecting rods

## ❑ ISAA Project (ESA Project)

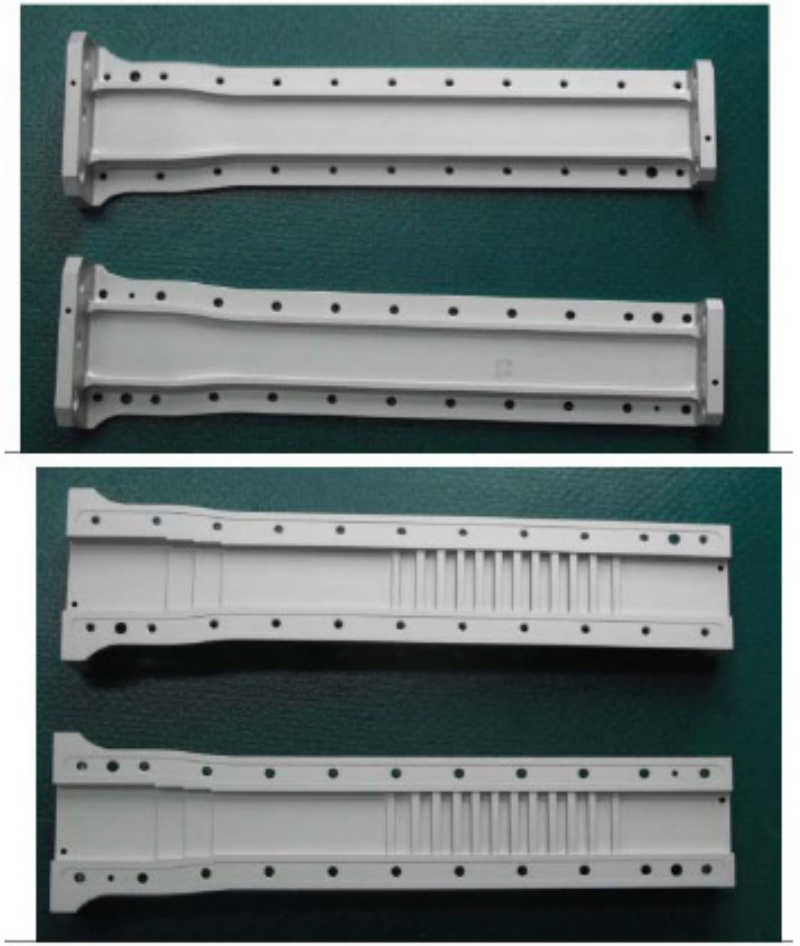
Space Systems: Design and manufacture of waveguides of satellite antennas

## ❑ DOC Project (ESA Project)

Space Systems: Design and manufacture of back cover of space capsule

The **ISAA Project** is an ESA Project involving Space Engineering spa and CIRA

- The objective of the activity is to demonstrate the performance of an Antenna system for satellite applications
- The design, manufacturing and RF test of antenna critical elements are also requested
- Among the others, one of the activities in charge of CIRA is the **feasibility study** regarding the **manufacturing of the antenna by using the EBM technology**
- The test case is the **KA Band low pass filter** to be manufactured by respecting challenging tolerance and surface finishing requirements



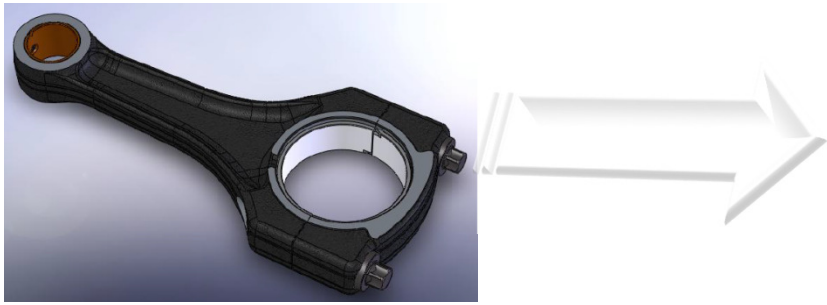
**TIMA** (Tecnologie Innovative per Motori Aeronautici a combustione interna a basso impatto ambientale ed elevata autonomia) is a **RITAM** project. RITAM (RIcerca su Tecnologie Avanzate per Motori) is a consortium whose partners are CIRA, CSM, CMD, UNINA, UNISA, CRDC

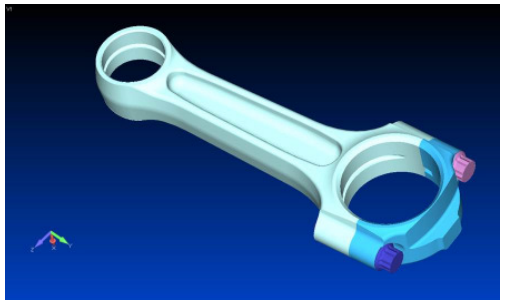
The RITAM-TIMA project has the objective to find innovative design solution for aeronautical engine parts to be manufactured by using the **ALM process**

## 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

- Design Logical Process:

- Connecting Rod
- Benchmark

→

- New Geometric
- Configuration
- (new typology)

→

- Re-sizing
- (new topology)

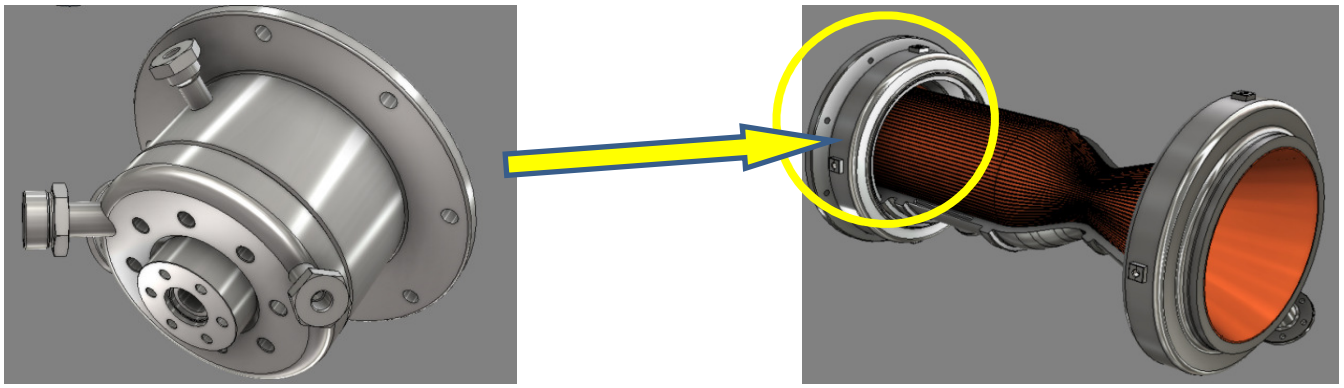
**The HYPROB Project** is funded by the Italian Ministry of Research through the National Aerospace Research Program (PRORA).

**The Main Target is of the Project :**

Ground demonstrator (L0X/LCH4 engines) design, manufacture and testing.

**The Lab mission is:**

Design and manufacture parts (back plate assembly of the injection head ) for L0X/LCH4 engine demonstrator by using EBM process.

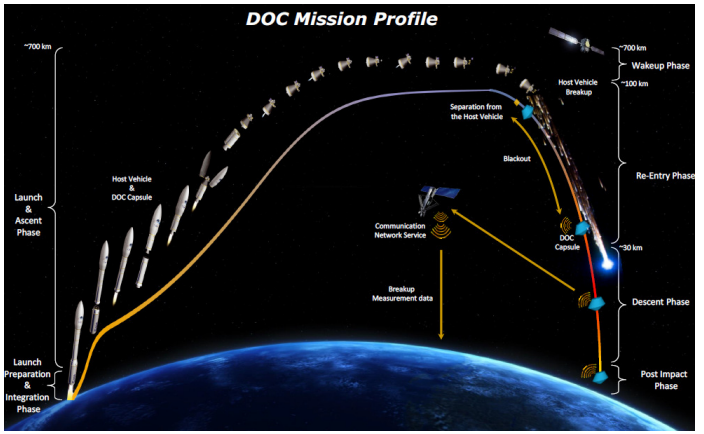


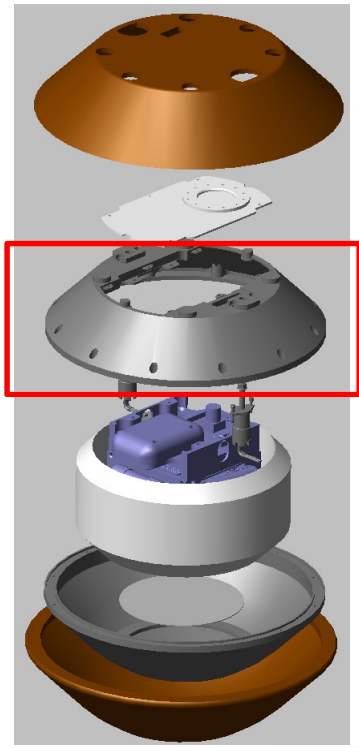
**Back plate assembly of the injection head** **Rocket engine demonstrator**

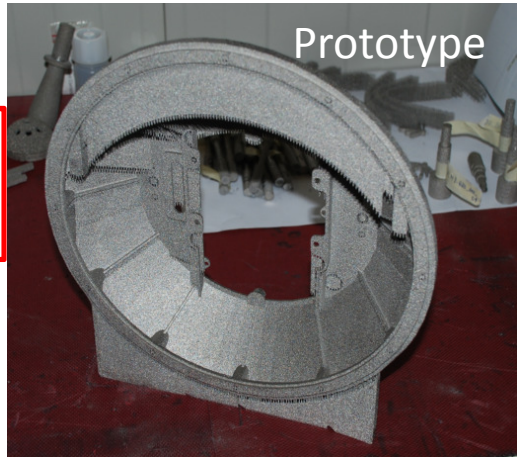
- The back plate assembly of the injection head is presently made in INCONEL 718 and it is produced with standard technologies (high-precision machining and brazing). In this project the **back plate assembly** will be to re-design and manufacture **using EBM technology**.
- Our **challenge** will be to re-design and manufacture the **Regenerative cooled thrust chamber.**

# The **DOC (**Demise Observation Capsule) **Project** is an ESA Project.

With the **DOC**, ESA will collect important information about the re-entry processes of launcher stages. The analysis of the re-entry data about objects re-entering the atmosphere will help in accurately predicting break-up altitudes, debris trajectories and ground impact footprint.






**The Lab final target:**

Design and manufacture the **Back cone of the space capsule** in titanium alloy by using EBM process.

It is the most important structural part. It connects the host vehicle to the frontal shield and to the avionics.

Even if the design is still not mature, the preliminary result shows that the conceived geometry respects the mass limits and the overall stiffness of the system is satisfactory.

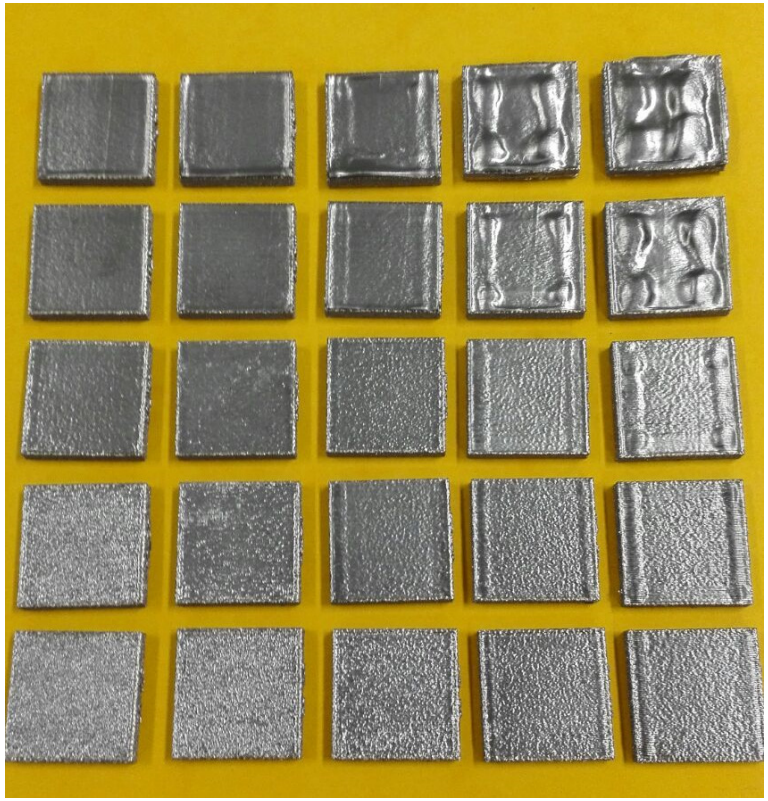
# EBM Process Parameter Optimization

## OPPLA (PRORA Project)

EBM process is a complex procedure depending upon different processing parameters.

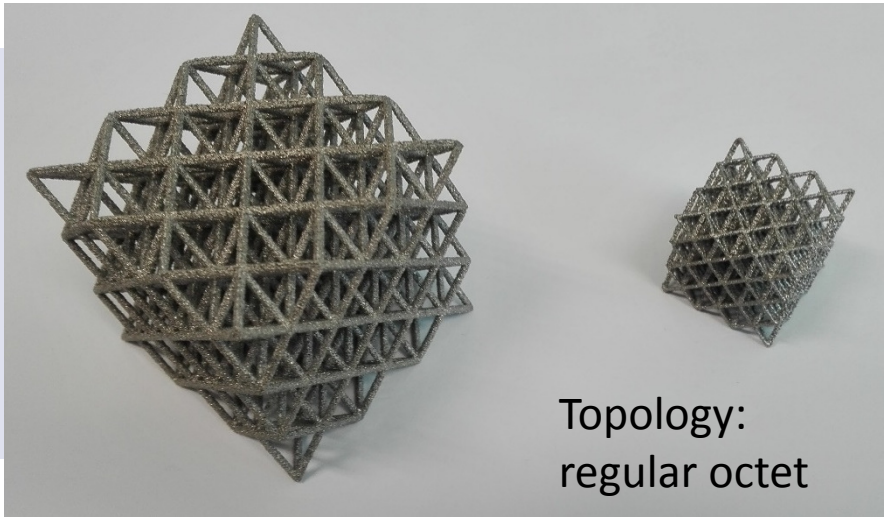
The final microstructures of EBM built are the result of complex combination of different processing parameters.

**Our goal is to establish the process parameters influence on the microstrucutral properties, geometrical and dimensional tolerances and roughness surfaces.**



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

**METMAT (PRORA Project)**



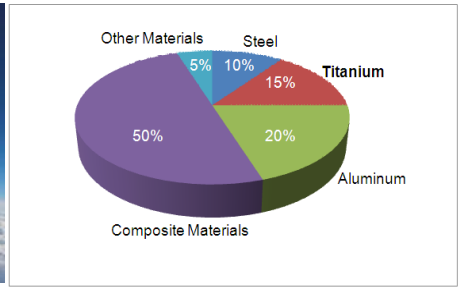

**<u>EBMed lattice structures</u>**:

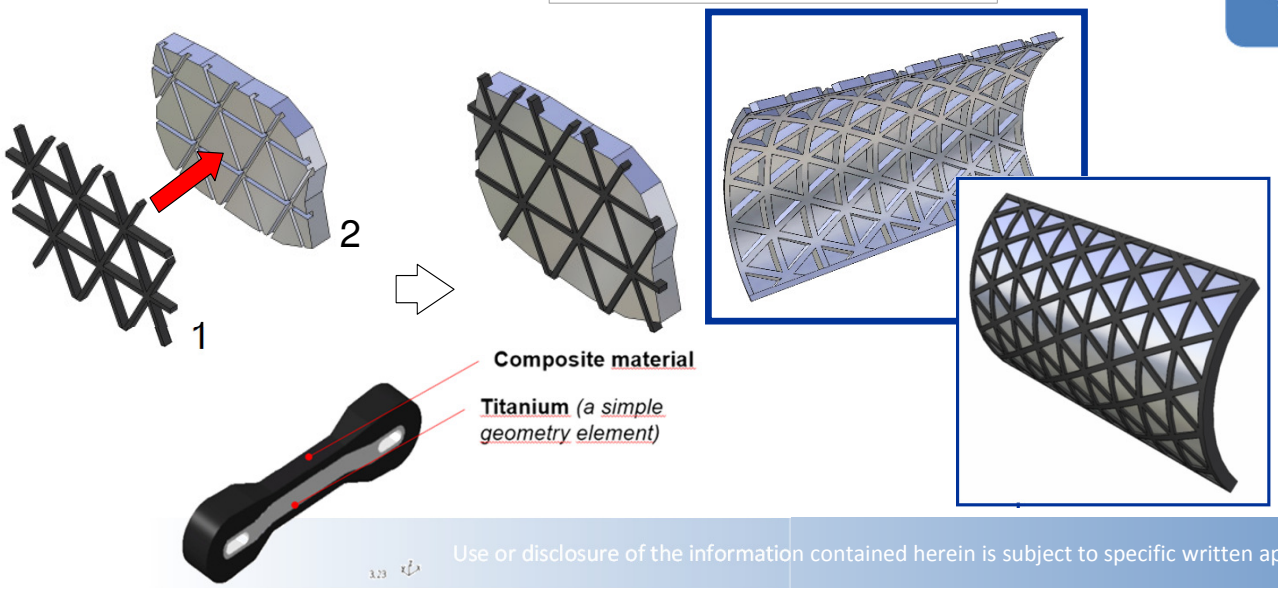
Investigation on the performances of lattice structures manufactured via EBM.

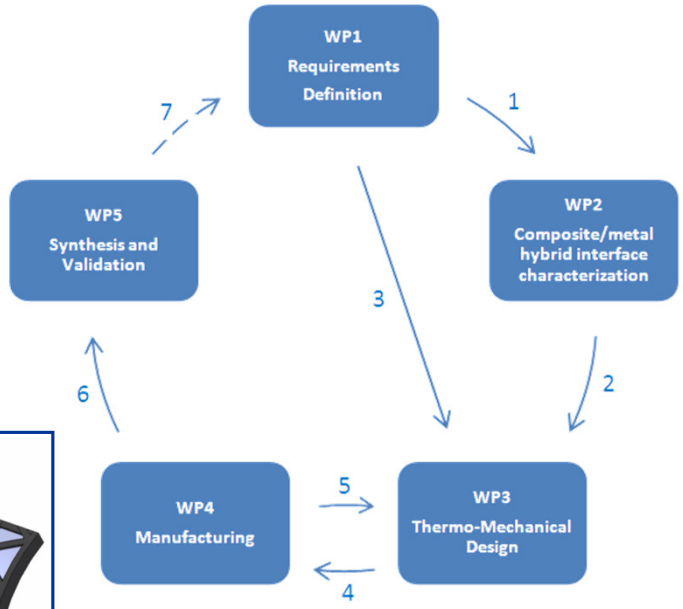
# HYBRIS: innovative technologies for high performance HYBRId metal/composite Structural component.

Engineering design, especially in aviation industry, is nowadays driven by the pressing demands for:

- reducing fuel consumption and the related contaminant emissions, in compliance with the guidelines of international law;
- reducing manufacturing costs related to the technologies and materials;
- reducing manufacturing time, enhancing assembly operations and facilitate maintenance of companies.



# Open Items

- **Full Characterization of EBMed Components**: Microstructural; Mechanical; Electrochemical; Surface and Dimensional.
- **Post Processing Treatments**
  - Powder Remove
  - Surface Finishing
  - Heat Treatments (HIP)
  - Machining
  - Coatings
- **Process Characterization (Robustness and repeatability)**
- **Near net shape Structures**: Design and Manufacturing
- ***Think additive***:

**Redesign of components from an additive point of view extending the design space (the designer can choose different design solution)**

# Thanks for your attention

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**Eng. Carmine Pirozzi**
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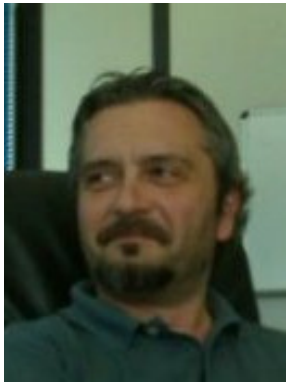

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