



Master ANIE per Industria 4.0

# Tecnologie 4.0 Manifattura Additiva

**Paolo Fino**

7 maggio 2019

Organizzato da





POLITECNICO  
DI TORINO

**IAM**  
Integrated Additive  
Manufacturing@PoliTo



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DI TORINO

# Additive manufacturing 4 ANTE: Scenario



POLITECNICO DI TORINO



# Additive Manufacturing @ POLITO



POLITECNICO DI TORINO

**Politecnico di Torino**  
Department of Applied Science  
and Technology



**Istituto Italiano  
di Tecnologia**

Centre for Sustainable Future  
Technologies CSF@PoliTo



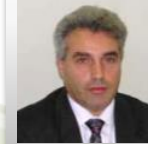
POLITECNICO DI TORINO

**Politecnico di Torino**  
Department of Management  
and Production Engineering



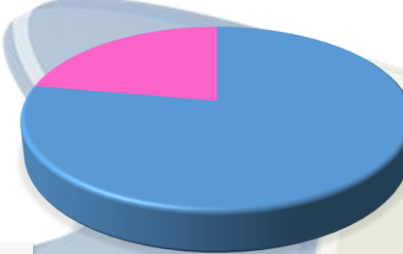
**Prof. Paolo Fino**

*Full Professor*



**Prof. Luca Iuliano**

*Full Professor*



**Federica Bondioli**

*Full Professor*



**Giulio Marchese**

*Assistant Professor*



**Sara Biamino**

*Associate Professor*



**Daniele Ugues**

*Associate Professor*



**Matteo Pavese**

*Associate Professor*



**Diego Manfredi**

*Researcher Technologist*



**Alessandro Salmi**

*Associate Professor*



**Paolo Minetola**

*Associate Professor*



**Eleonora Atzeni**

*Associate Professor*



**Marco Actis Grande**

*Full Professor*



**Mariangela Lombardi**

*Associate Professor*

**Emilio Bassini**

*Research fellow*



**Alberta Aversa**

*Assistant Professor*

**Enrico Virgillito**

*PhD student*



**Massimo Lorusso**

*Researcher*



**Flaviana Calignano**

*Assistant Professor*



**Manuela Galati**

*Research fellow*

**Alessandro Carrozza**

*PhD student*

**Antonio Sivo**

*PhD student*



**Abdollah Saboori**

*Assistant professor*

**Federico Bosio**

*PhD student*

**Giulio Cattano**

*Research fellow*

**Simone Parizia**

*PhD student*

**Gabriele Piscopo**

*PhD student*

**Aresh Mazdai**

*PhD student*



POLITECNICO DI TORINO



# Additive Manufacturing @ POLITO



ISTITUTO ITALIANO DI TECNOLOGIA  
CENTER FOR SPACE HUMAN ROBOTICS

**Polito @ Tecnogrande S.p.A.**



M250 EOS



M270 EOS



DED



EBM - TiAl Intermetallics

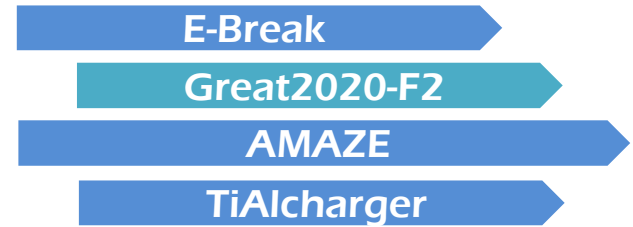


**Partnership AVIO – Polito  
Regional research project**

**Blow Powder Tech.  
Large components**



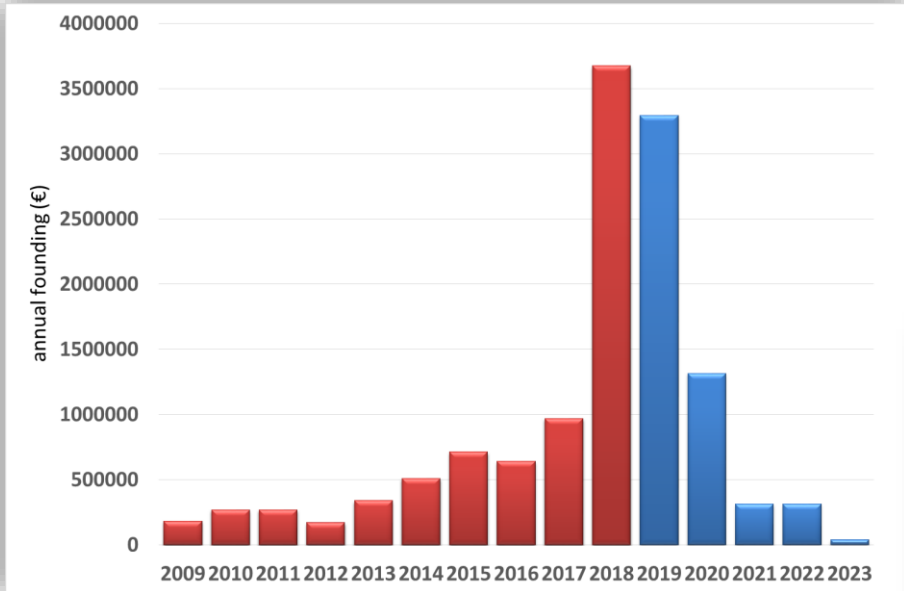
**Partnership Prima Industrie – Polito  
European research project**



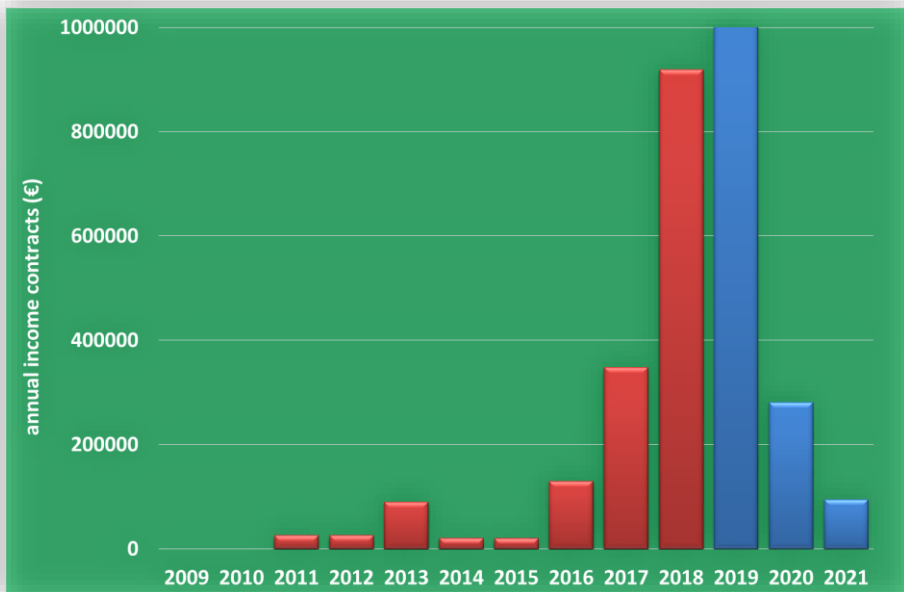
- Getready
- Cluster
- Borealis
- Helmet



# Additive Manufacturing @ POLITO

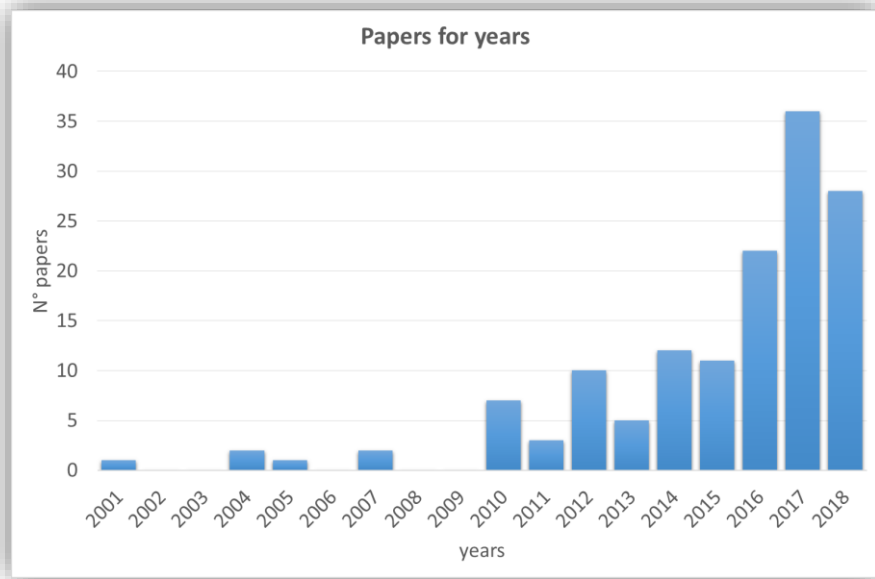


**External resources 16'111'762 €**  
**Internal resources for facilities 3'000'000 €**

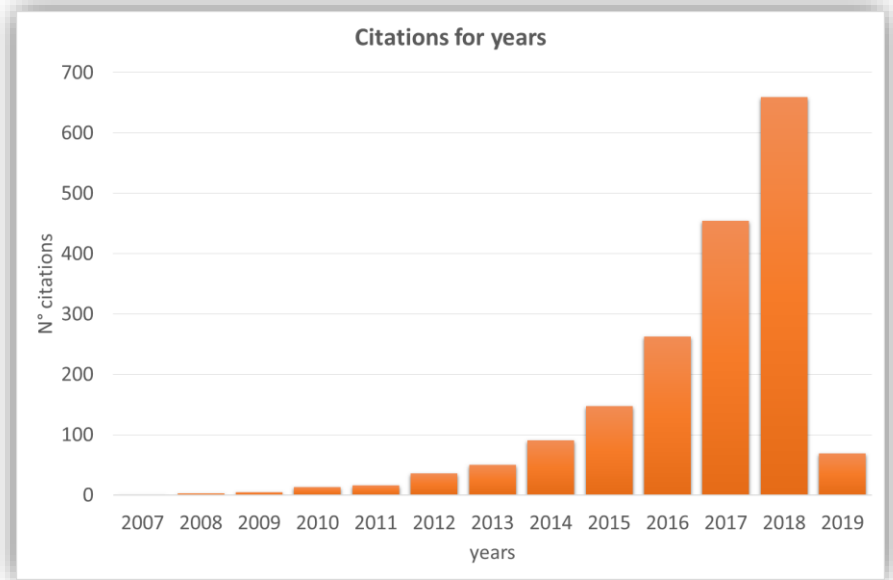




# Additive Manufacturing @ POLITO



**141 papers on AM topics**  
**1785 citations in the last 10 years**



### Most cited papers:

**2012 International Journal of Advanced Manufacturing Technology**

**183 citations**

**2011 Intermetallics**

**161 citations**

**2007 Rapid Prototyping Journal**

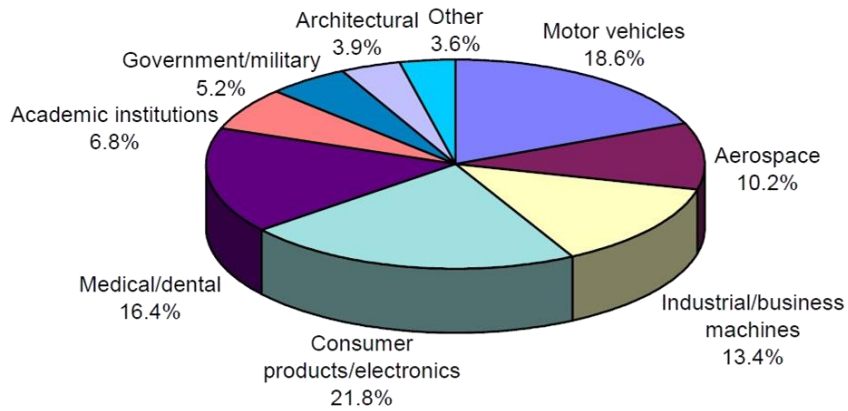
**140 citations**

**2013 Materials**

**131 citations**

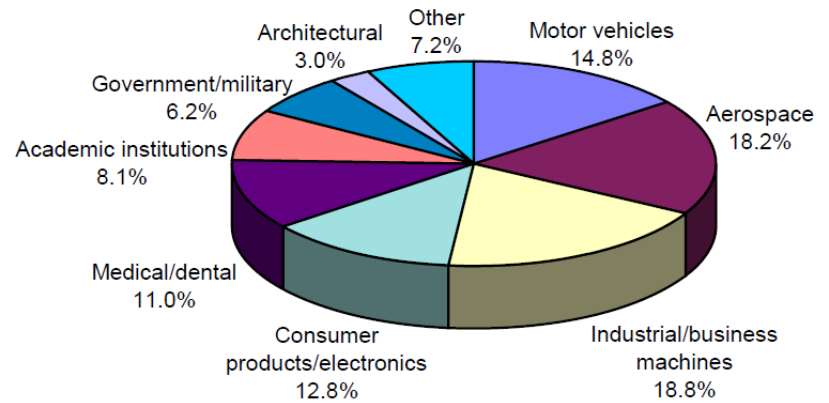
# Market Status

## INDUSTRIAL SECTORS



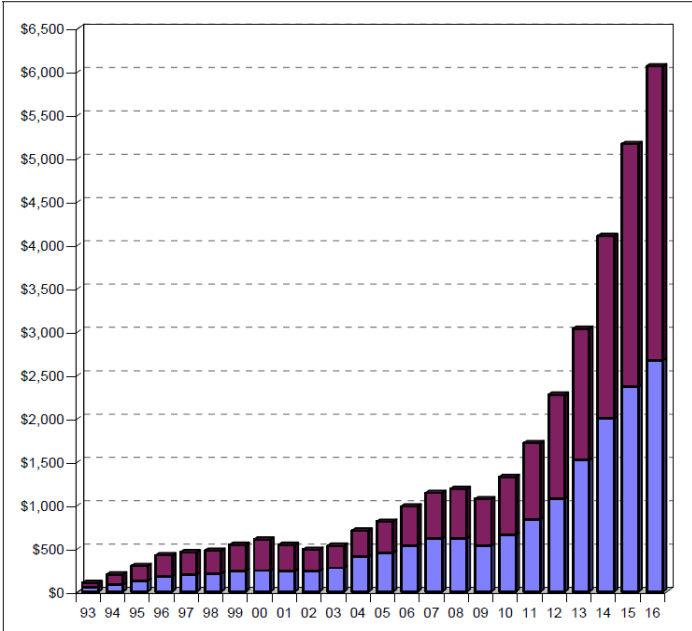
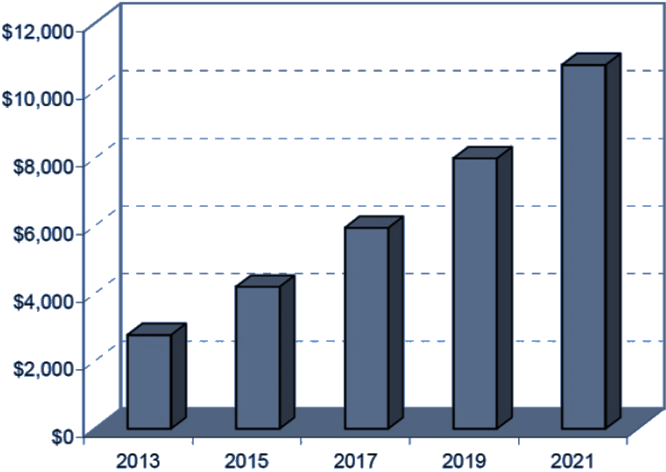
2013

2017



# Market Status

## MARKET OPPORTUNITY AND FORECAST

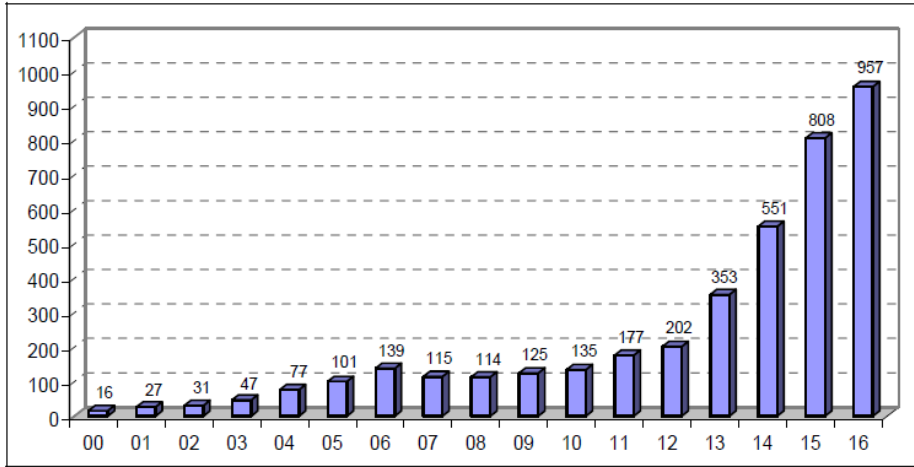


Source: Wohlers Associates, Inc.



# Market Status

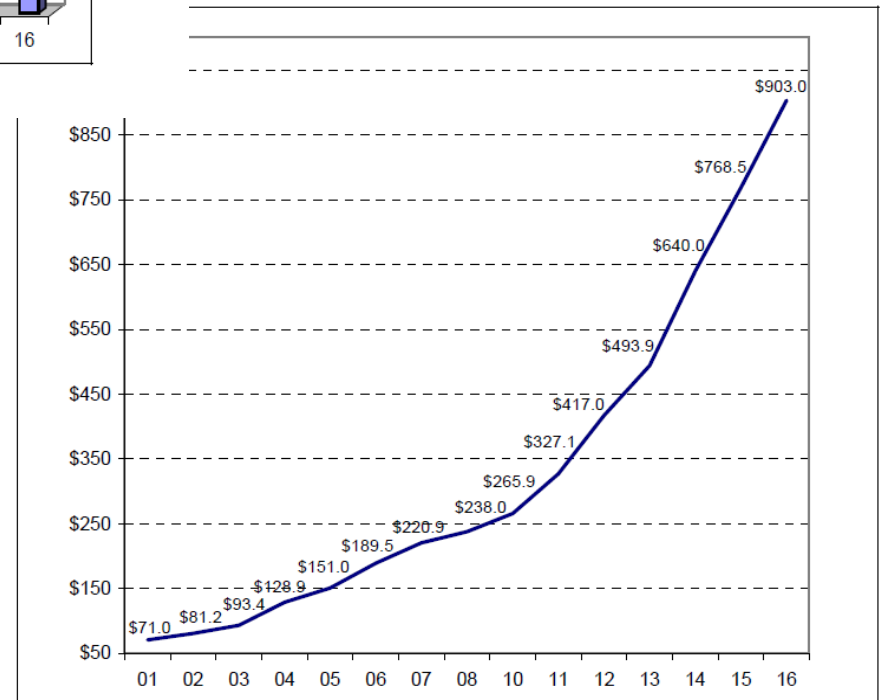
## ➤ Metal AM



Source: Wohlers Associates, Inc.

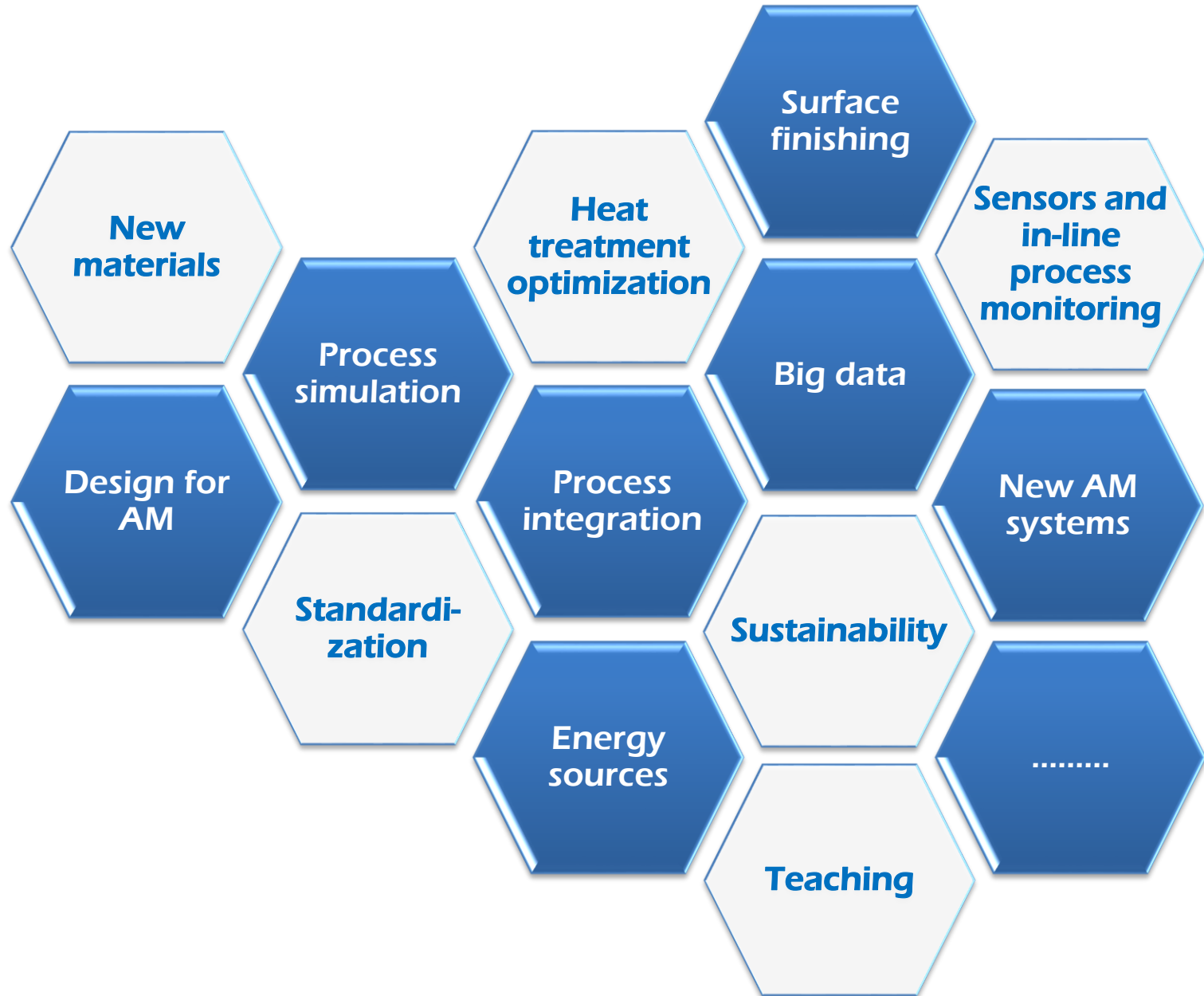
## AM systems Market

## Raw Materials Market



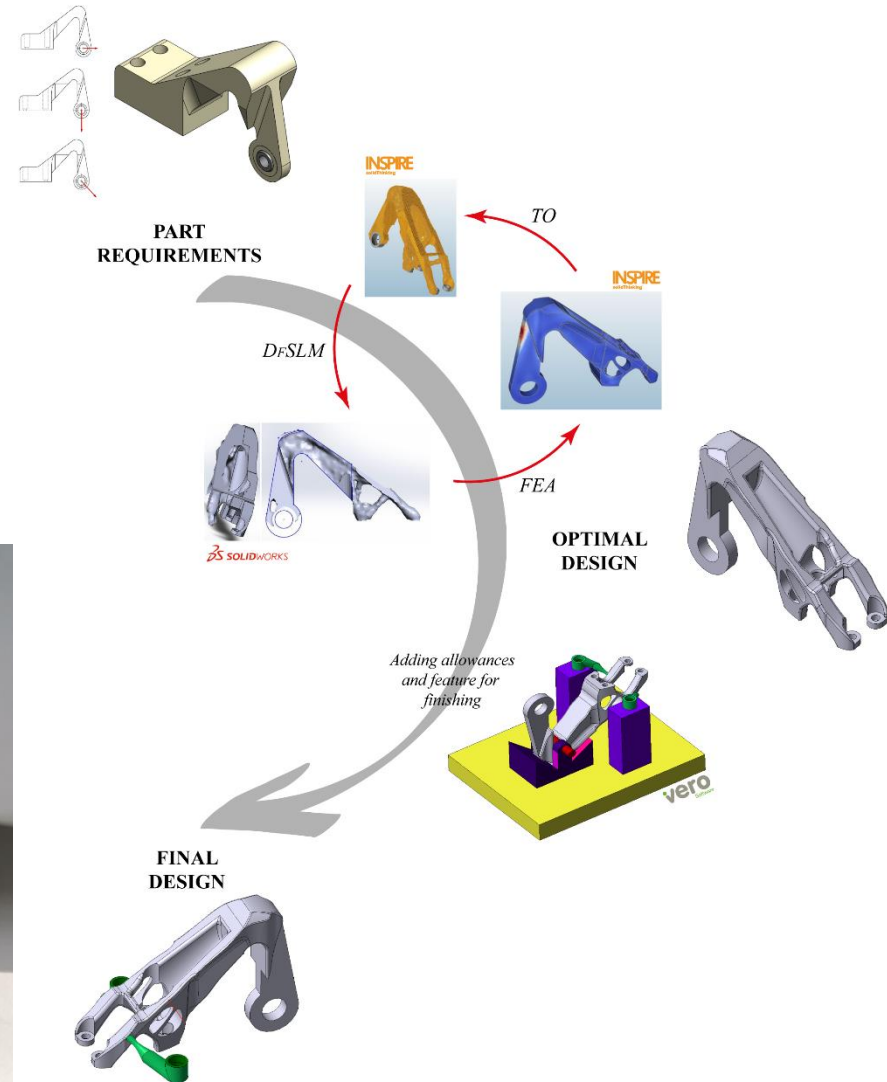
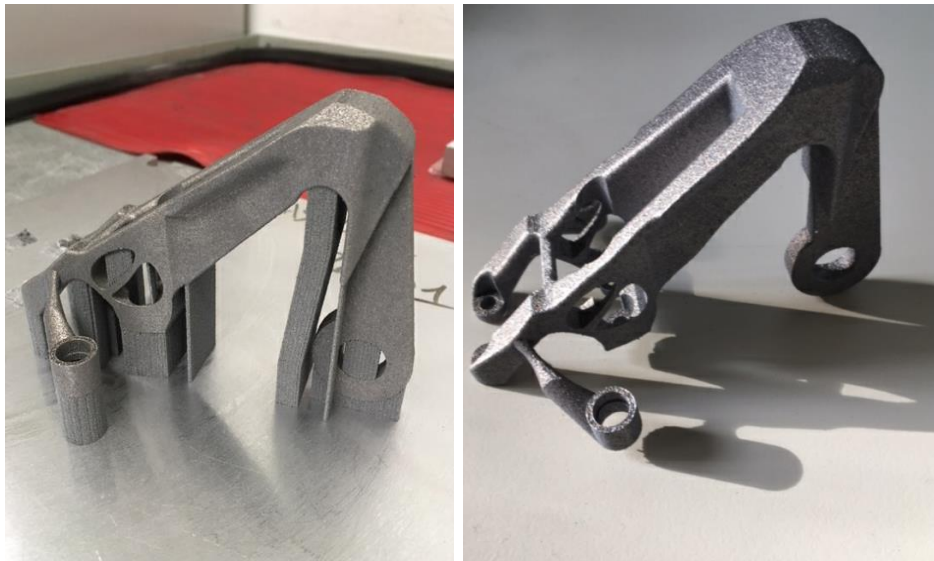


# Activities IAM@POLITO

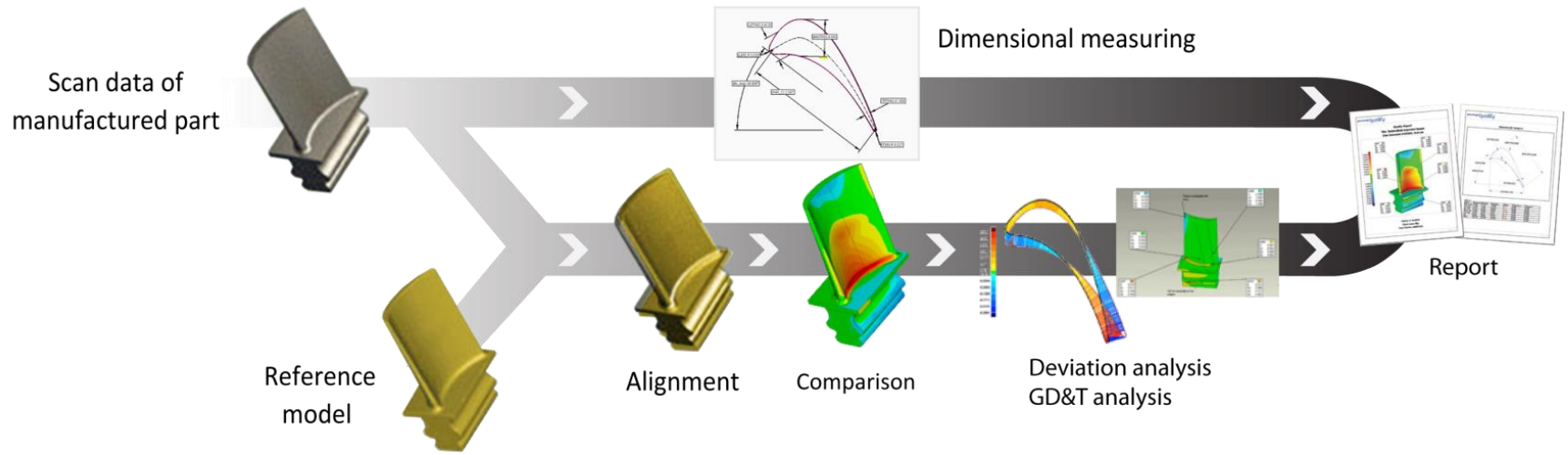


## ➤ Design for AM

DFAM methodology is enhanced encompassing also the post-processing and finishing phases. In details, the requirements for the finishing phase (metal allowances, sacrificial features for clamping, ...) should be considered in the design of the part in order to fully exploit the AM potential



## ➤ Computer Aided Inspection (CAI) and Reverse Engineering

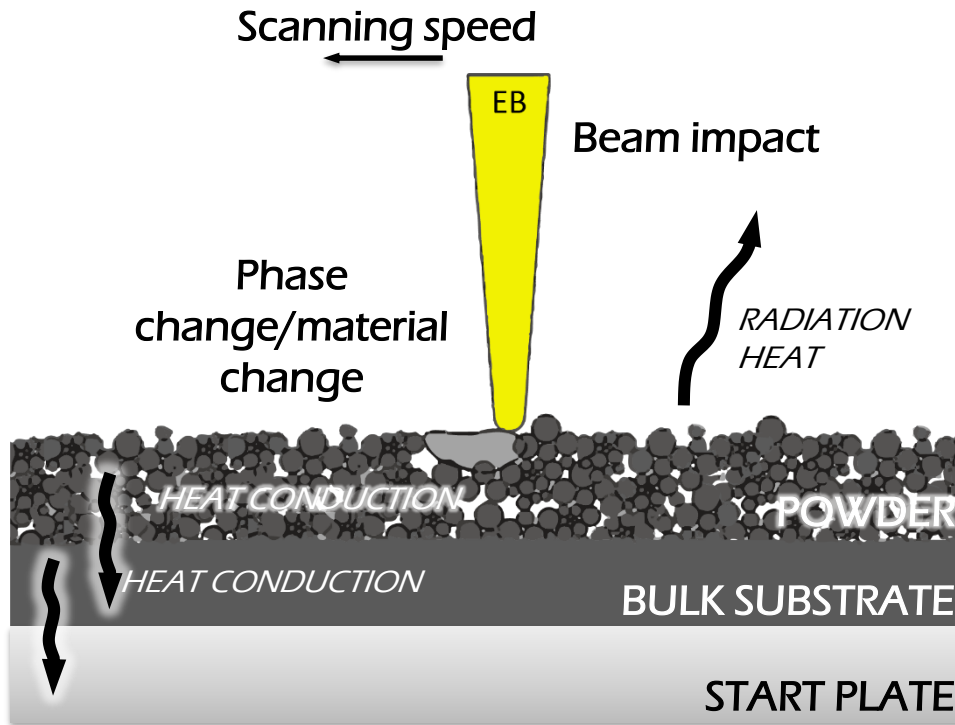


When a part exists but not the drawing the CAD model can be generated using data from 3D-digitising (non-contact scanner system) and the RE methodology.

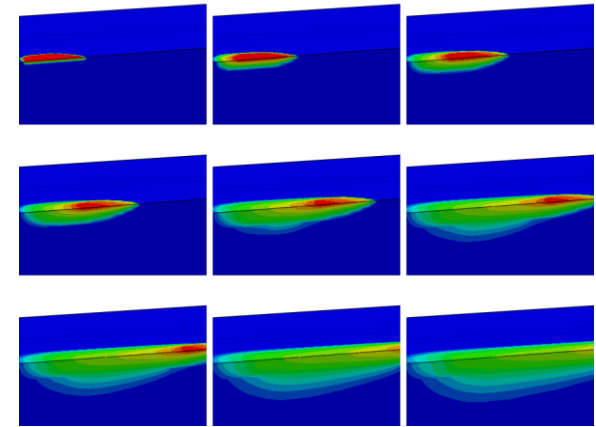


# Activities IAM@POLITO

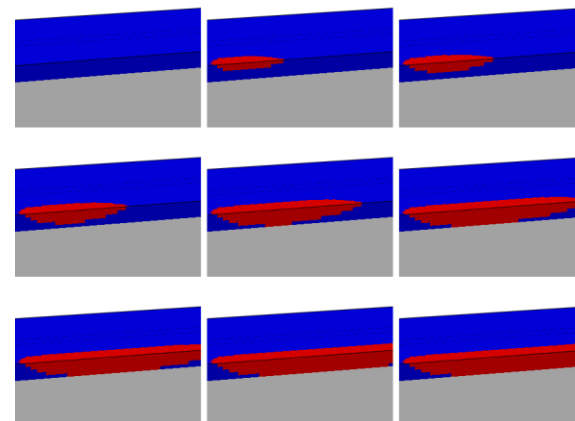
## ➤ Process simulation



## Study of temperature distribution



## Study of solidification evolution

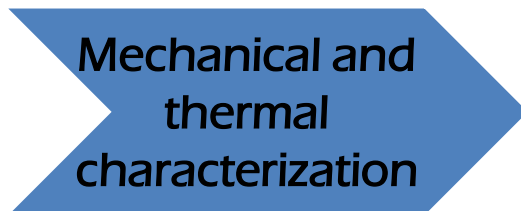
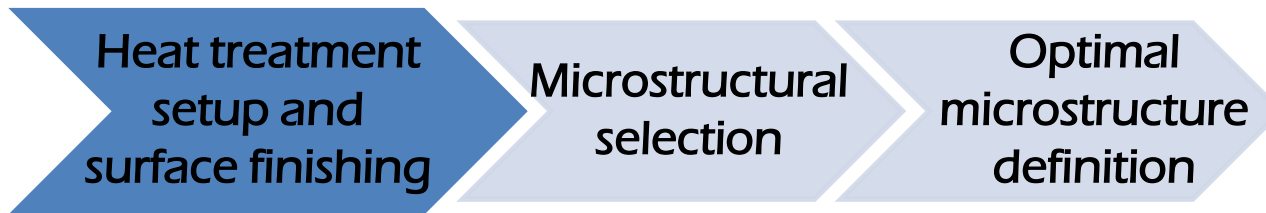


material

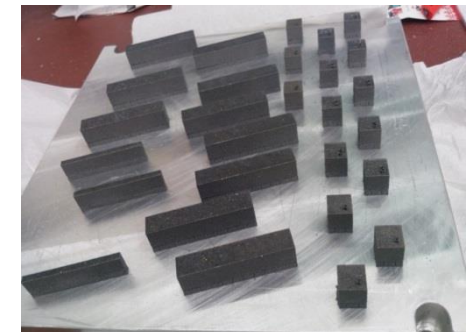
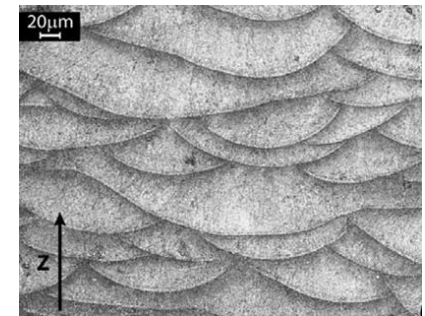
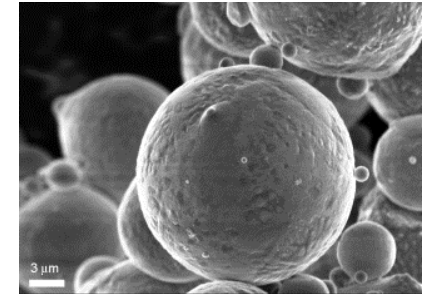
- POWDER
- BULK SUBSTRATE
- SUBSTRATE

# Activities IAM@POLITO

## ➤ Process optimization

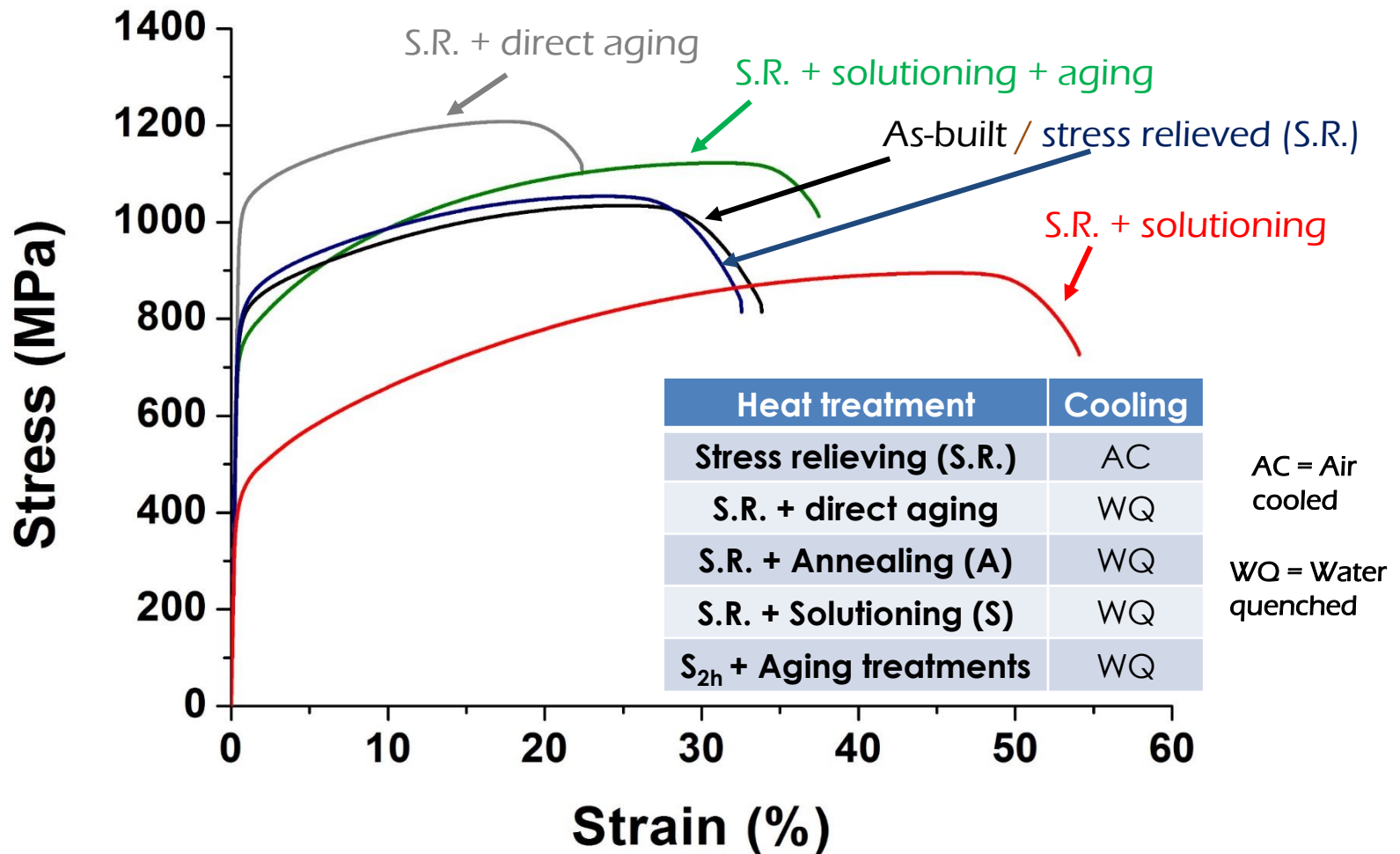


AISI10Mg



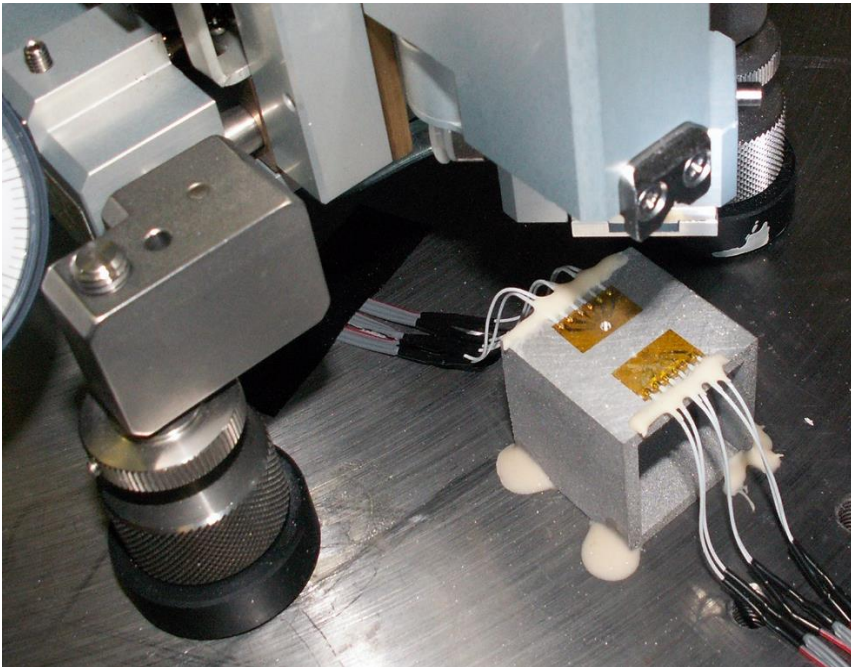
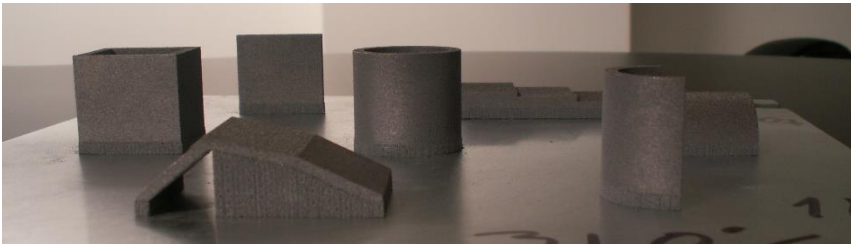
## ➤ Thermal treatments and surface finishing

Study of the effect of thermal treatments on tensile behaviour

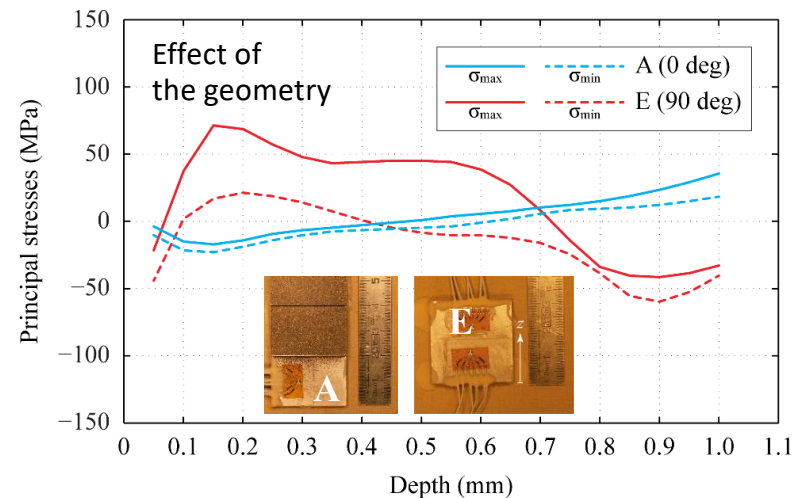
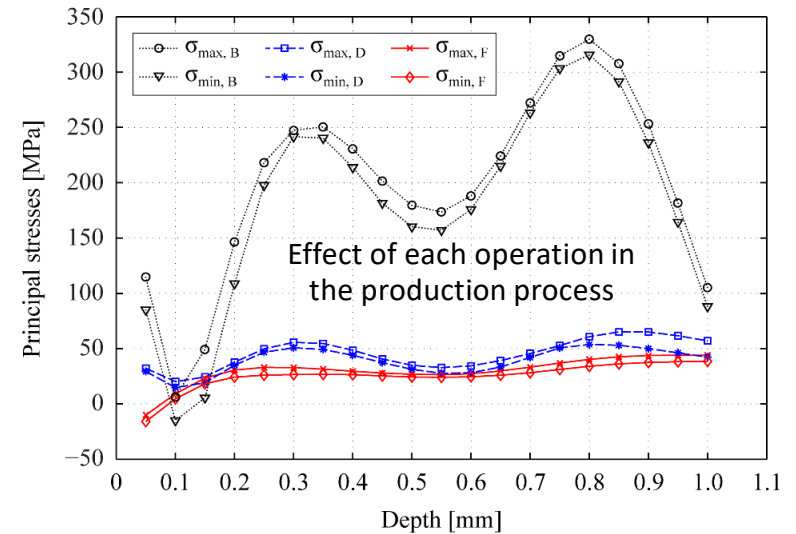


## ➤ Thermal treatments and surface finishing

Evaluation of residual stresses at the macro-scale by hole drilling strain gauge method



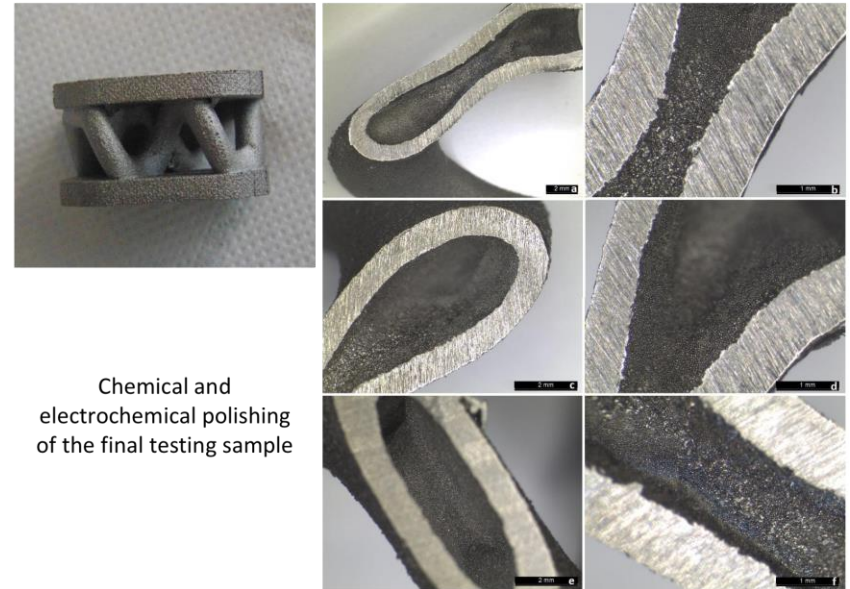
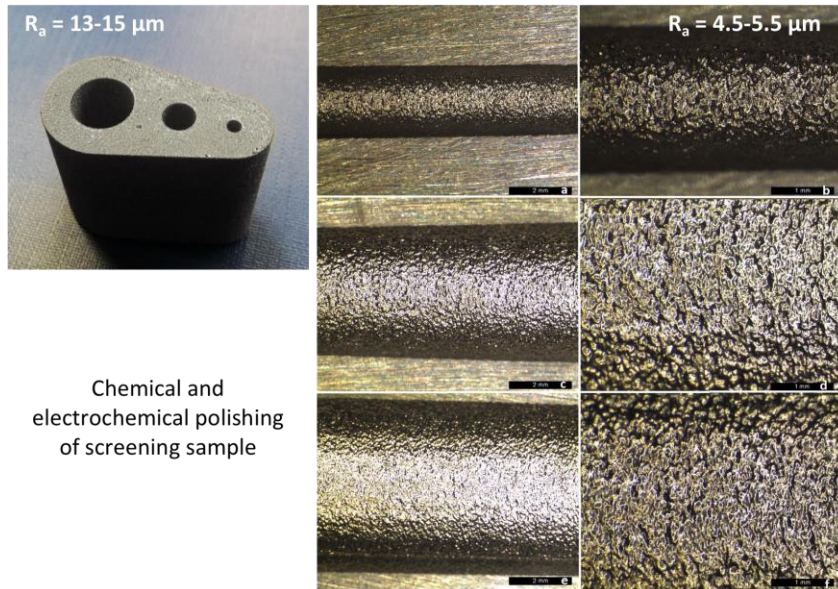
as-built | post thermal treatment | after the shot-peening





## ➤ Thermal treatments and surface finishing

Study of the effect of thermal treatments on tensile behaviour



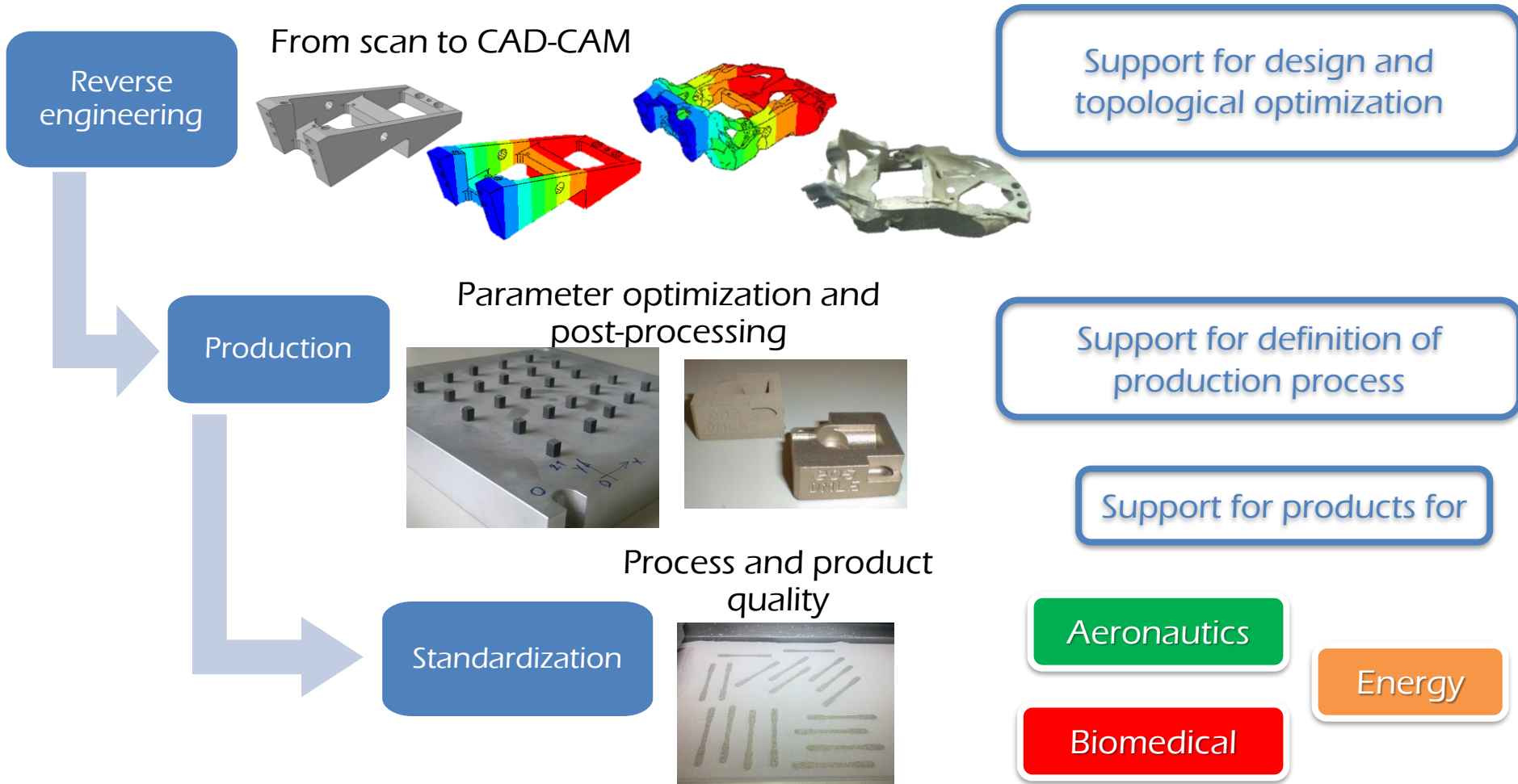
Finishing to improve:

- Aesthetic features
- Dimensional tolerances
- Roughness
- Specific functionalities
- Fatigue resistance

Set-up of conditions for traditional and not traditional methods

## ➤ Integration with traditional processes

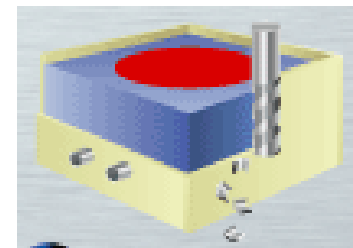
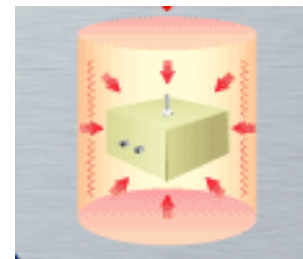
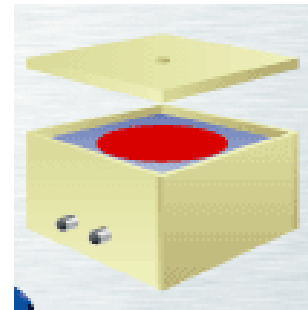
### AM production of spare parts



## ➤ New processes of NNS

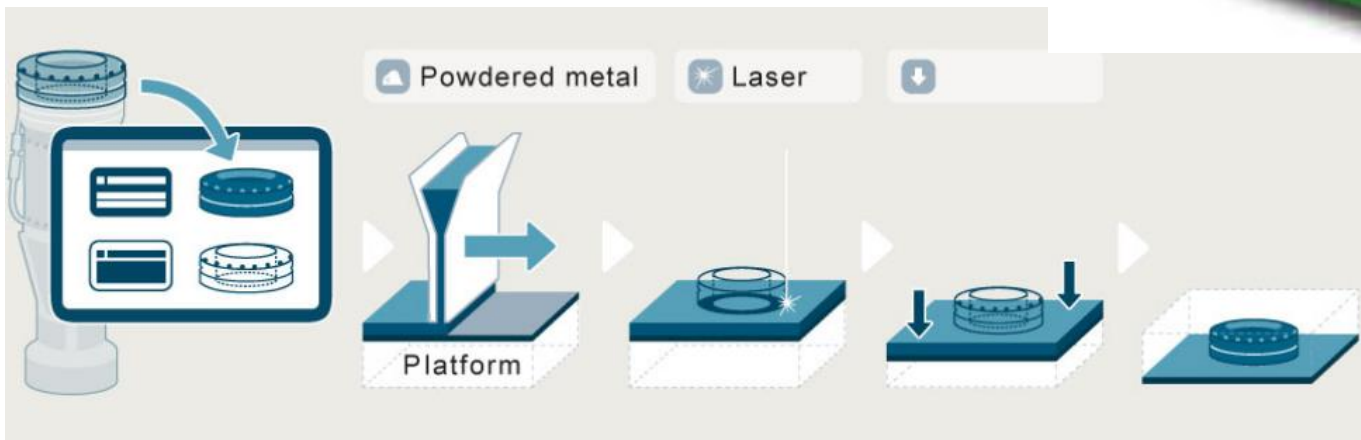
Main steps:

- Definition of line-guides for component design
- Development of simulation models
- Development of moulds and tools for production
- Optimization of HIP conditions
- Optimization of strategies for mould removal
- Optimization of thermal treatment of the final component.



## ➤ Integration with MES and other information systems

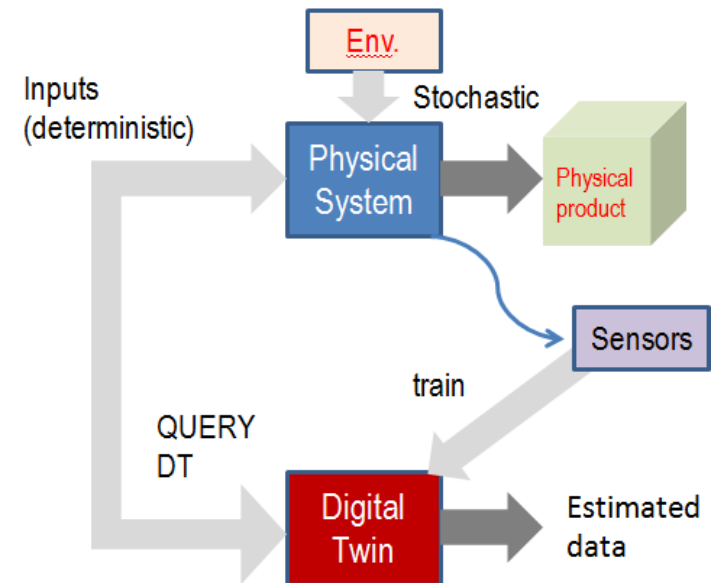
- AM quite different from a traditional manufacturing systems
  - supplies, steps, etc
- Closer to semiconductor manufacturing
- Integration with commercial MES not trivial
  - Need adaptation of MES to support it
- Essential to move to mass production
- Activities ongoing with a major MES provider



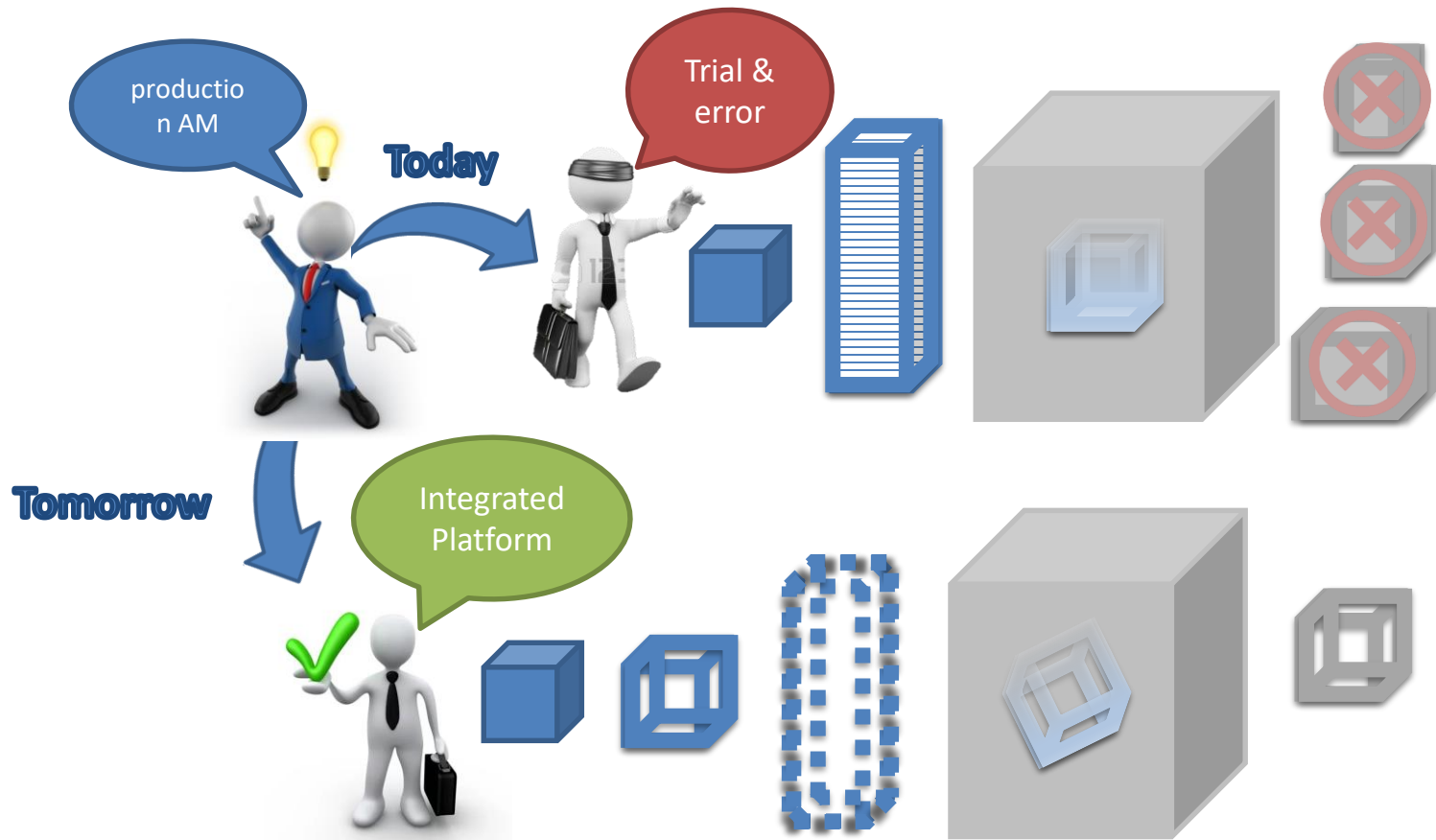
## ➤ ICT support for process optimization

1. Optimization of semi-manual phases of the process
  - Optimization of support structures at design time
2. Construction of Digital Twins (DT) for AM production
  - Based on invasive or non-invasive sensors
  - Include non-deterministic environmental disturbances
  - Train the DT
  - Includes big-data management, AI techniques for clustering and inference.

Activities planned in the near future



# Approccio all'additive manufacturing



## ➤ Sustainability

Optimization of AM processes in view of economic and environmental sustainability in order:

- To reduce raw materials;
- To optimize part efficiency
- To reduce component weight
- To reduce tool use
- To reduce investments and stocks
- To optimize the efficiency of the *supply chain* and to develop new sale models(*simply ways and with shorter delivery times*)





## ➤ Teaching

Career in AM in the frame of Master of science in Mechanical engineering;  
specialized courses about:

- Design for Additive Manufacturing,
- Materials for Additive Manufacturing,
- Technologies for Additive Manufacturing.

[https://didattica.polito.it/pls/portal30/gap.a\\_mds.espandi2?p\\_sdu=32&p\\_cds=37](https://didattica.polito.it/pls/portal30/gap.a_mds.espandi2?p_sdu=32&p_cds=37)

Course (in English) in the frame of Master of science in Mechanical engineering  
about Additive Manufacturing Systems and materials

[https://didattica.polito.it/pls/portal30/gap.pkg\\_guide.viewGap?p\\_cod\\_ins=04SOSOD&p\\_a\\_acc=2019&p\\_header=S&p\\_lang=EN](https://didattica.polito.it/pls/portal30/gap.pkg_guide.viewGap?p_cod_ins=04SOSOD&p_a_acc=2019&p_header=S&p_lang=EN)

Specializing master in AM with courses about:

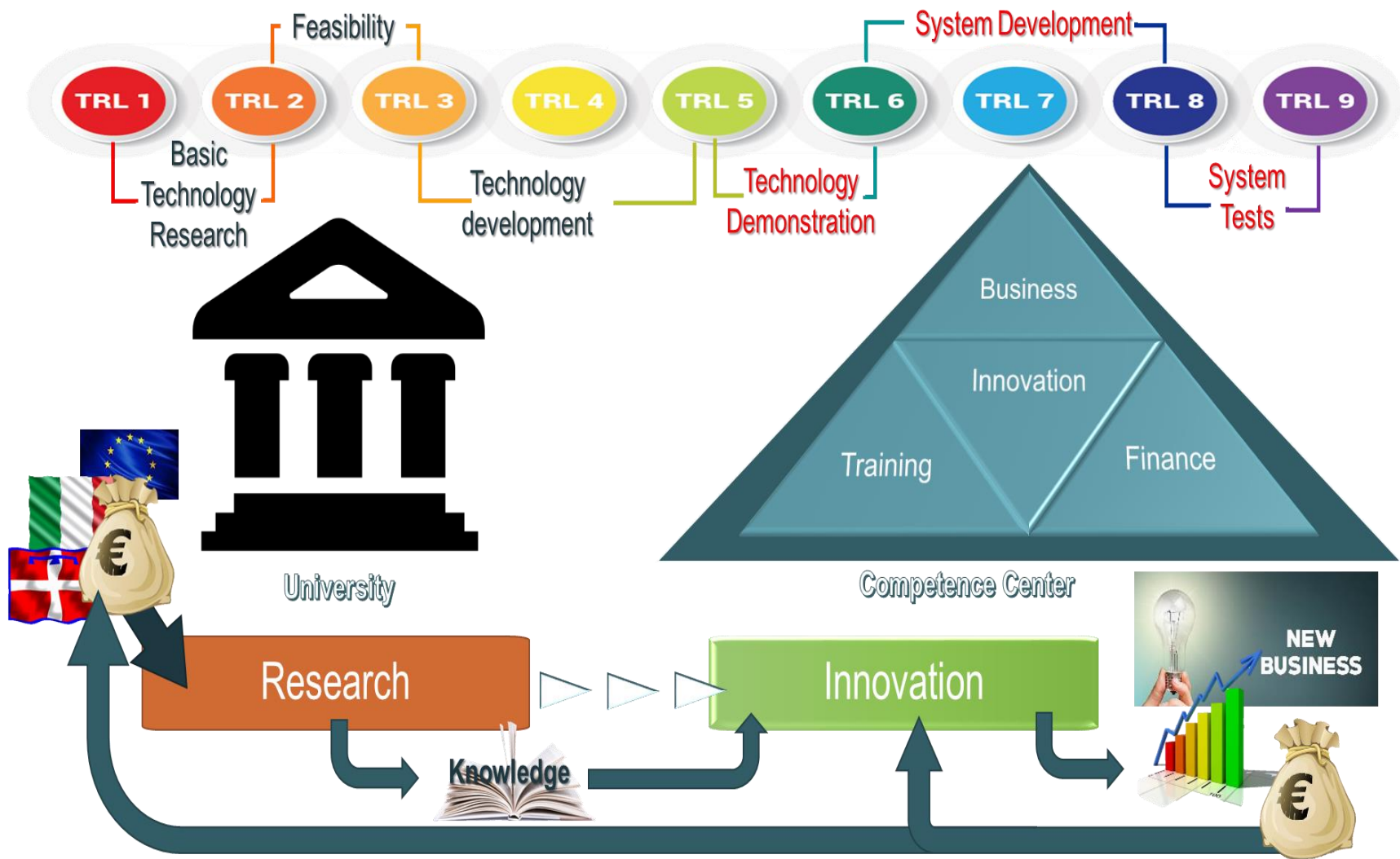
- Design,
- Materials,
- Systems,
- Production management,
- Supply chain management,
- ICT platforms.

[https://didattica.polito.it/master/additive\\_manufacturing/2017/introduction](https://didattica.polito.it/master/additive_manufacturing/2017/introduction)

[https://didattica.polito.it/master/additive\\_manufacturing/2018/at\\_a\\_glance](https://didattica.polito.it/master/additive_manufacturing/2018/at_a_glance)



# Competences Center: Approach





POLITECNICO  
DI TORINO



UNIVERSITÀ  
DEGLI STUDI  
DI TORINO

**Technology providers:** STMicroelectronics,  
Siemens, Prima Industrie, Reply, Consoft Sistemi,  
AizoOn Consulting, Cemas Elettra, Illogic;

**Service providers:** TIM, Agilent Technologies, 4D-  
Engineering, Altran Italia, IREN;

**Technology chain Leader:** FCA, GE Avio,  
Leonardo, GM Global Propulsion Systems, Thales  
Alenia Space;

**End users:** ENI, Michelin Italiana, SKF, Italdesign,  
Merlo, FEV Italia;



# CIM4.0 - Key Numbers

- ✓ *2 universities*
- ✓ *24 large and medium enterprises*
- ✓ *More than 8 M€ as in-kind instruments and facilities (hw & sw)*
- ✓ *About 6 M€ for pilote-lines instruments*
- ✓ *About 10 M€ of personnel contributions from partners, besides 3 M€ of CIM4.0 personnel*
- ✓ *3.6 M€ of partners fees*
- ✓ *MISE fouding of 10.6 M€*
- ✓ *127 people from industrial partners and 22 people from universities*

# CIM4.0: Services

## Innovation and Technological Maturation

- Technology scouting and assessment
- Chain projects, pilot lines

## Technology Transfer

- Support for enterprises, projects of enterprise network
- Pilot lines for business cases
- Support for start up creation

## Training

- Professional personnel, managers
- Pilot lines for teaching factory

## Finance (by involving financial institutes)

- Credit
- Risks

## Services

- Investments in infrastructures
- Infrastructure exploitation (Services)

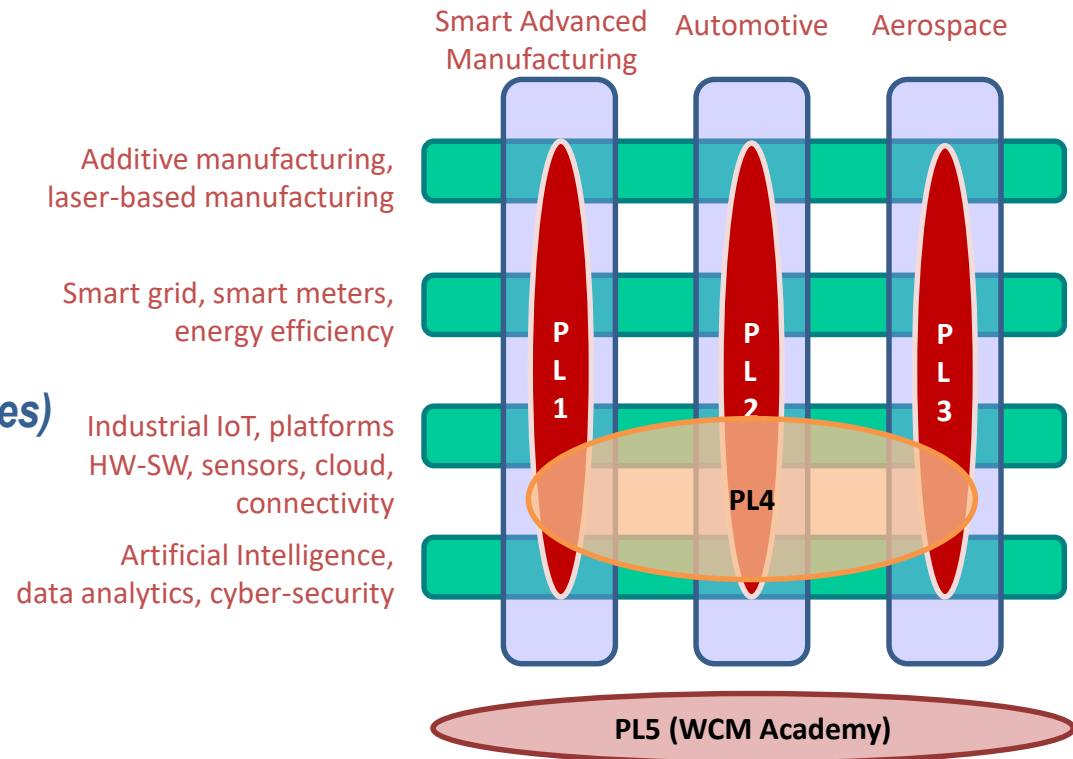
**Pilot Line 1:** Additive manufacturing for Smart Advanced Manufacturing

**Pilot Line 2:** Additive manufacturing per automotive

**Pilot Line 3:** Additive manufacturing per aerospace

**Pilot Line 4:** Virtual simulation e digital twinning

**Pilot Line 5:** World Class Manufacturing



# CIM4.0: Activities

