ADDITIVE MANUFACTURING E NUOVE FILIERE PRODUTTIVE

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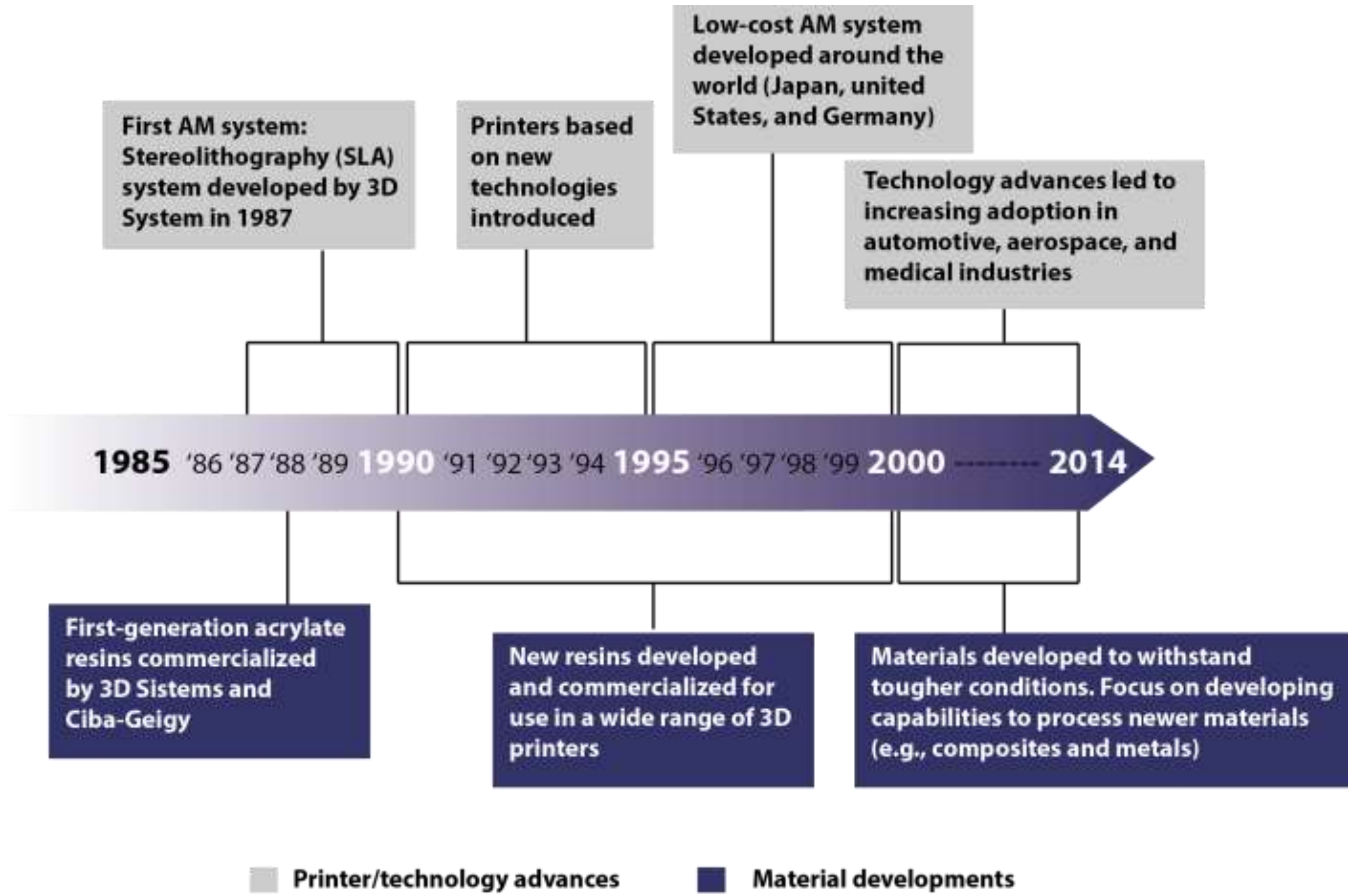
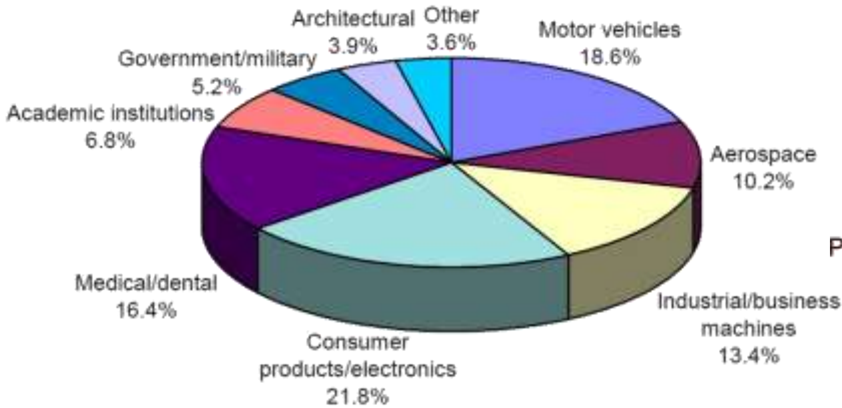
Evolution of AM



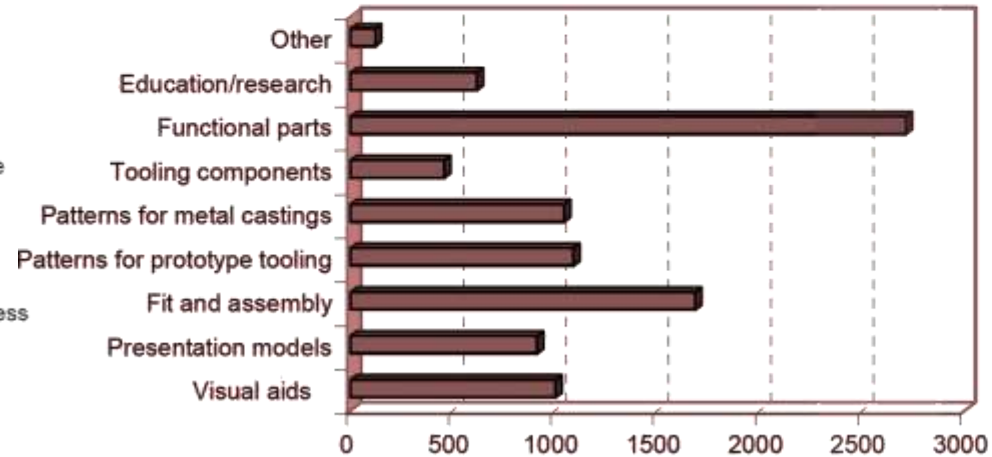
Source: Deloitte University; Wohlers Associates, Additive manufacturing and 3D printing state of the industry, 2012

State of the Art

INDUSTRIAL SECTORS

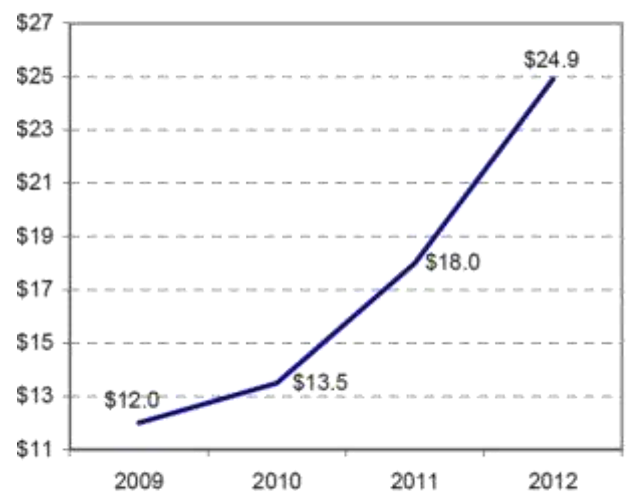


HOW COMPANIES ARE APPLYING AM PROCESSES



MARKET OPPORTUNITY AND FORECAST

REVENUE FROM METALS IN MILLION OF $



Source: Terry Wohlers Report 2013 - Annual Worldwide Progress Report

Strategy to share competences

Politecnico di Torino
DIGEP

AMTech Research Group

Prof. Luca Iuliano
Full Professor

CAD/CAE/CAM and 3D scanning systems

Advanced CNC machining and additive manufacturing

Politecnico di Torino
DISAT

Prof. Paolo Fino
Full Professor

Materials Science and Technology

CSHR@IIT

Prof. Fabrizio Pirri
IIT Center Coordinator

AM@POLITO

ISTITUTO ITALIANO DI TECNOLOGIA

Polito @ Tecnogrnada Spa

M250 EOS
CoCr alloy

ISTITUTO ITALIANO DI TECNOLOGIA
CENTER FOR SPACE HUMAN ROBOTICS

M270 EOS
Lightweight
Composites
SMA

Arcam A2
Intermetallics
Superalloy
Ceramics

2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015

Partnership AVIO – Polito
Regional research project

EBM - TiAl Intermetallics

Blow Powder Tech.
Alloy development
Large components

PRIMA INDUSTRIE

BOREALIS

Gamma Titanium Aluminides

Applications

Aircraft engine

LPT

GEnx

Automotive applications

Turbocharger wheel

Requirements for high temperature rotating components:

- Creep resistance
- Oxidation resistance over 700°C
- Specific strength similar to Ni-Based alloys
- Room temperature ductility ≥ 1%
- Fracture and Fatigue resistance.

$TiAl$ and Ti_3Al intermetallics: promising alternative to heavy Ni-superalloys (II)

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- low density materials (4 g/cm^3 vs 8 g/cm^3 Ni-base superalloys)

- specific strength comparable to Ni-base superalloys

- good oxidation and corrosion resistance up to 700 °C

So titanium aluminides promising for the last stages of the low pressure turbine in aeroengines or components in special turbochargers in automotive applications giving an interesting weight reduction of the components

Second generation alloys

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Other chemical elements were added: Cr increases ductility, Nb and Ta increase oxidation resistance

< 5 at%: **2nd generation alloys**

- Ti-48Al-2Cr-2Nb (General Electric)
- γ-TAB (GKSS)
- Ti-46.5Al-4(Cr,Nb,Ta,B) (Plansee)

Third generation alloys

It is under investigation the increasing of alloying elements (both amount and kind) in order to further improve the properties of this kind of materials

5 - 10 at% Nb: **3rd generation alloys**

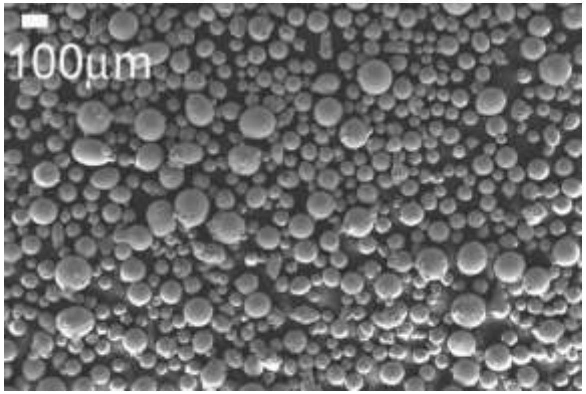
- γ -TNB alloys (GKSS)

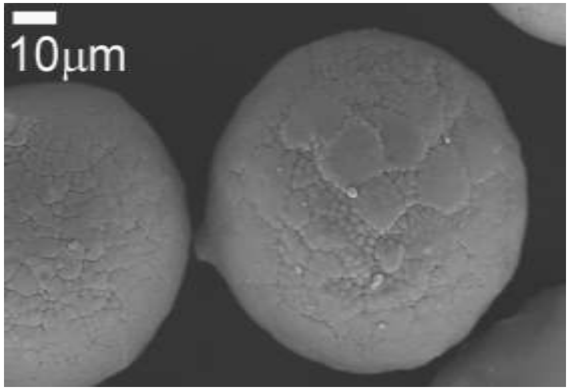
1 - 3 at% Mo: - γ -TNM alloys (MUL)

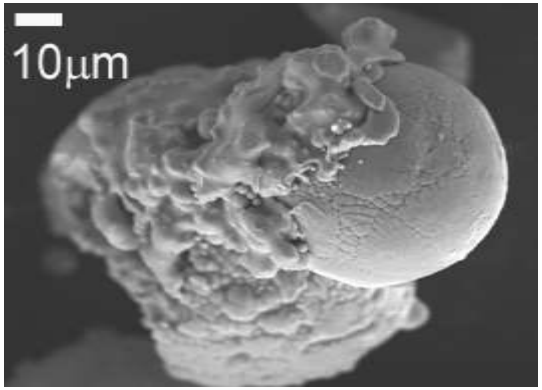
Ti-47Al-8Nb-2Cr

Ti-43.5Al-4Nb-1Mo-0.1B

Powder







Spherical particles

Powder defects

Powder	defects (%)	BET area (m^2/g)
A	16	0.036±0.002
B	15	0.028±0.002

EBM optimization : Main process parameters

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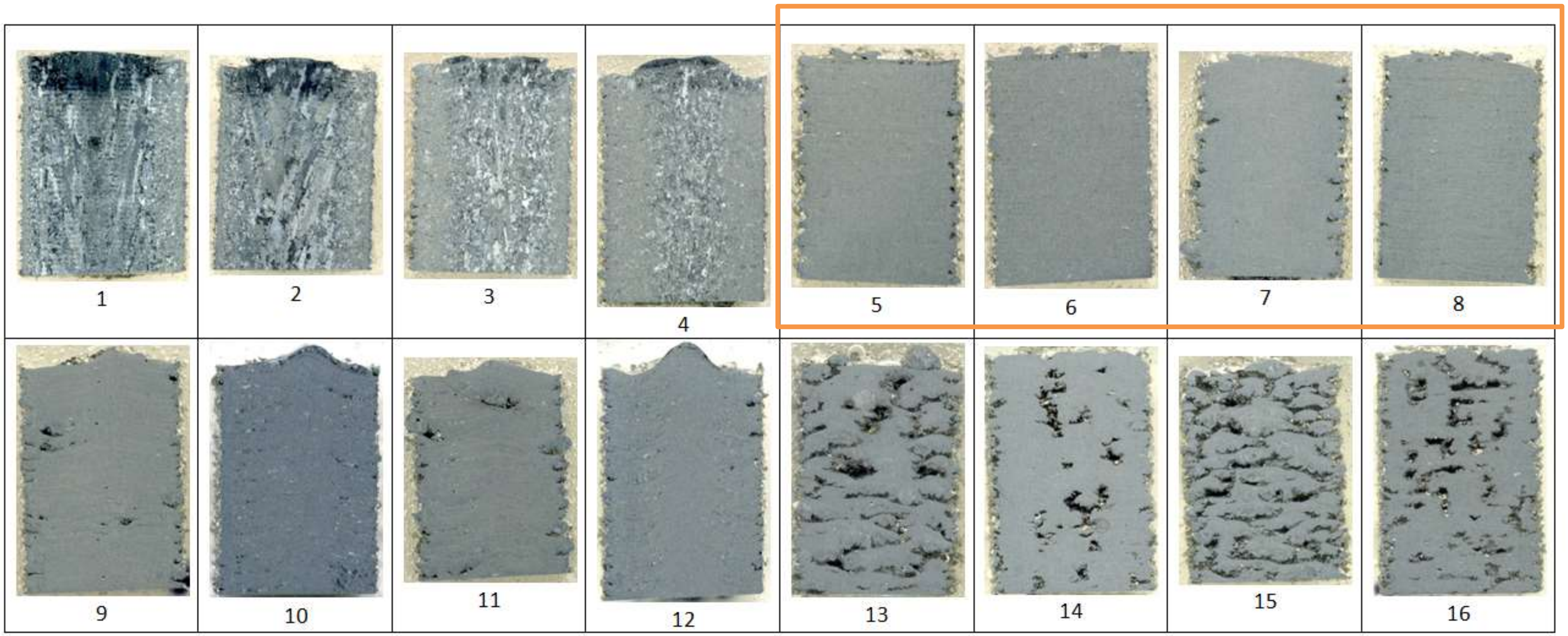
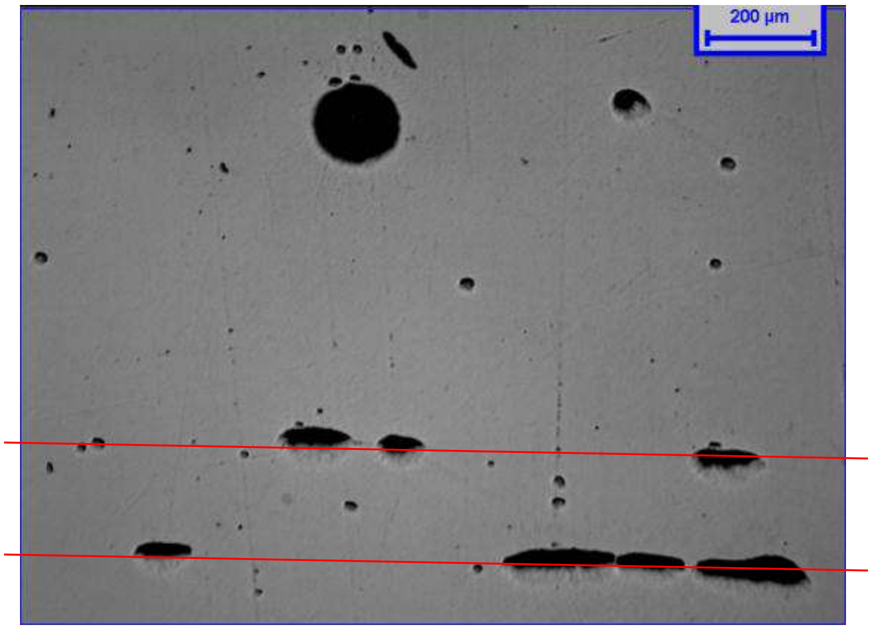
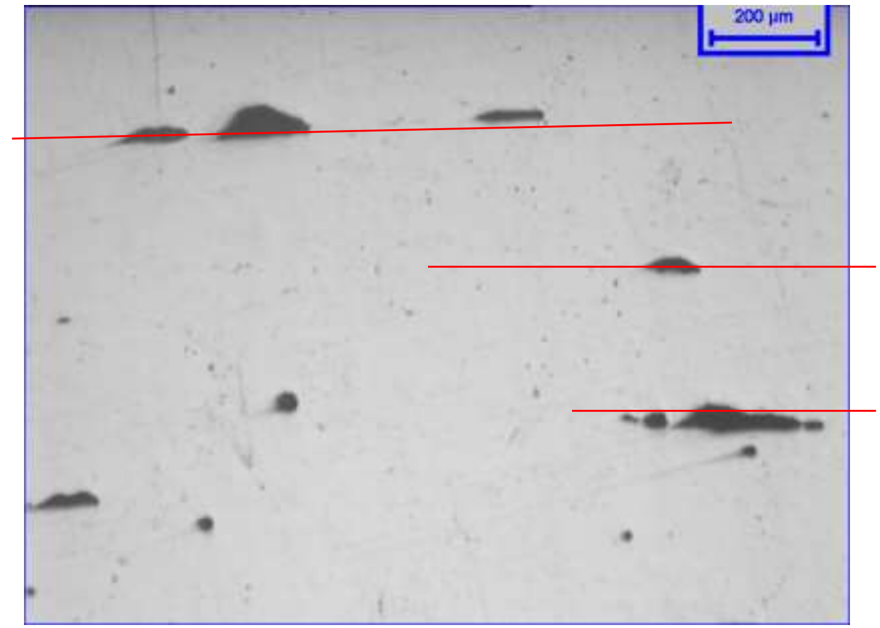
Optimal window for the process parameters with homogeneus fine equiassic microstructure with residual porosity less than 1%



Process optimization: residual porosity

Grow direction





Elongated pores -> process optimization is needed

HT Effect

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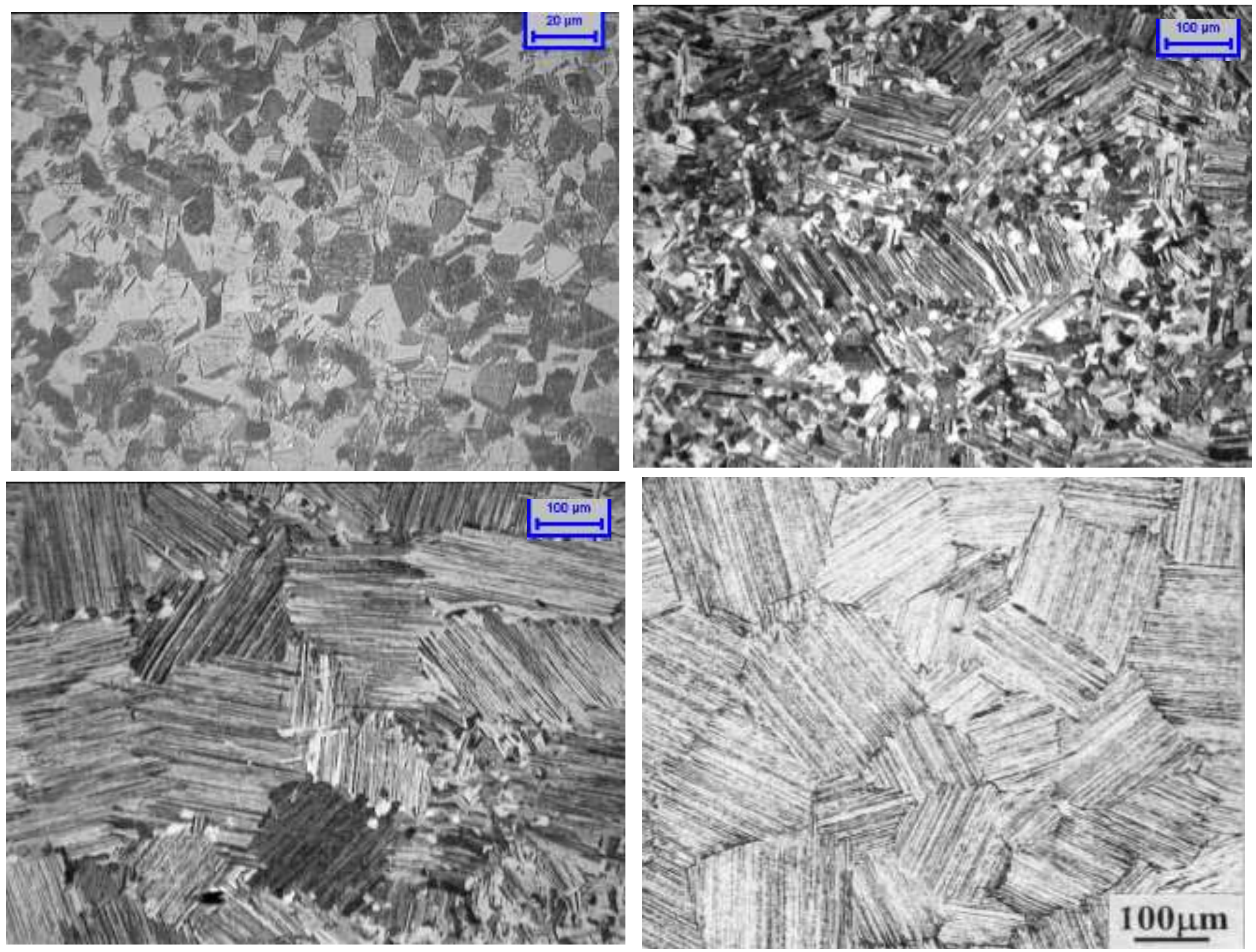
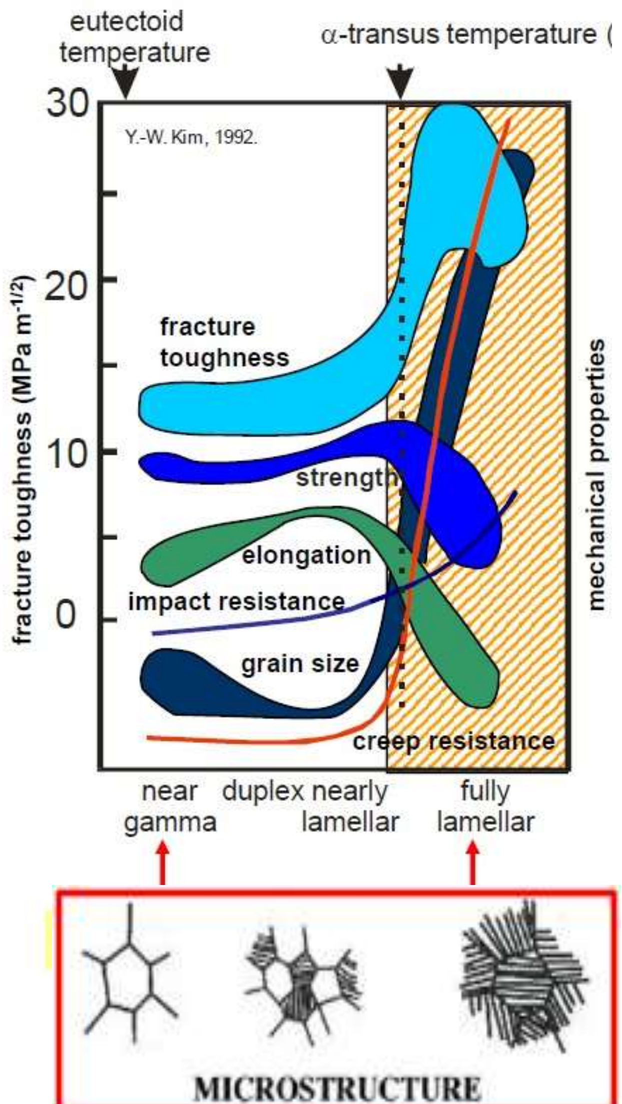
- Equiassic or Near γ (NG)
- Duplex (D)
- Near lamellar (NL)
- Fully lamellar (FL)



Relation Mechanical properties/ microstructure



Aircraft Application

Low pressure turbine blades

Genx

LPT

γ-TiAl Turbine Blade

Requirements for high temperature gas turbine structural application:

- Creep Resistance
- Oxidation resistance over 700°C
- Specific strength similar to Ni-based
- Room temperature ductility ≥ 1 %
- Fracture and fatigue resistance

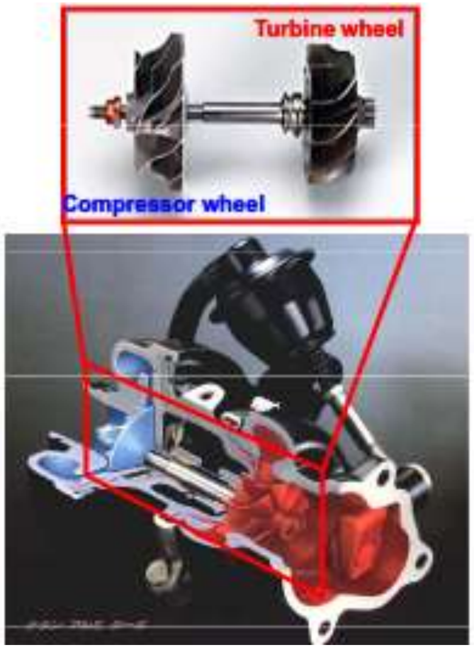
γ-TiAl Alloys:

- **48-2-2** Ti-48Al-2Cr-2Nb (at%)
  2° generation;
- **HNb** Ti-(45-47)Al-2Cr-8Nb (at%)
  3° generation, high oxidation resistance
- **TNM** Ti-43.5Al-4Nb-1Mo-0.1B (at%)
  3° generation , β solidifying alloy, improved RT ductility and strength

Automotive Application

TiAlCharger

Turbocharger Wheel



Turbocharger:

- Increase power output
- Improve fuel-efficiency

Light weight TiAl Turbine wheel:

- Improve performance
- Further improve fuel-efficiency
- Reduction in emission

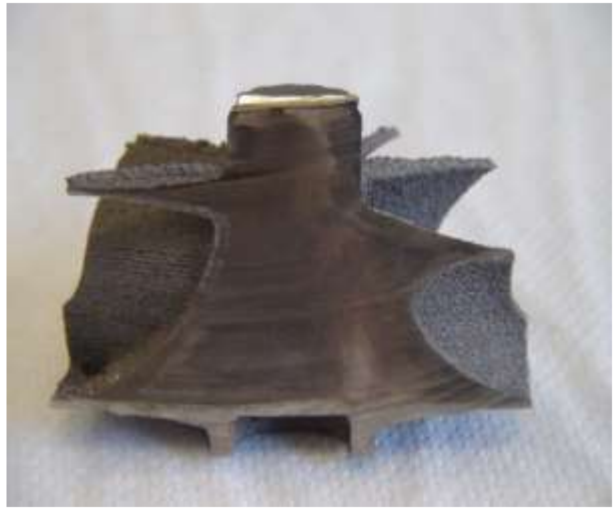
Material requirements and Alloy Design:

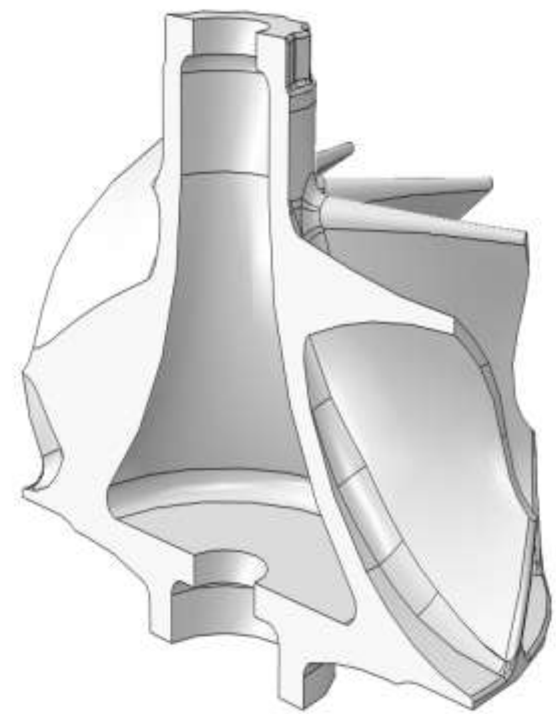
- Oxidation resistance: Nb and Si;
- Room temperature ductility: Cr
- Creep resistance: Si
- High temperature strength: Al and Nb optimization

RNT650 TiAl Alloy

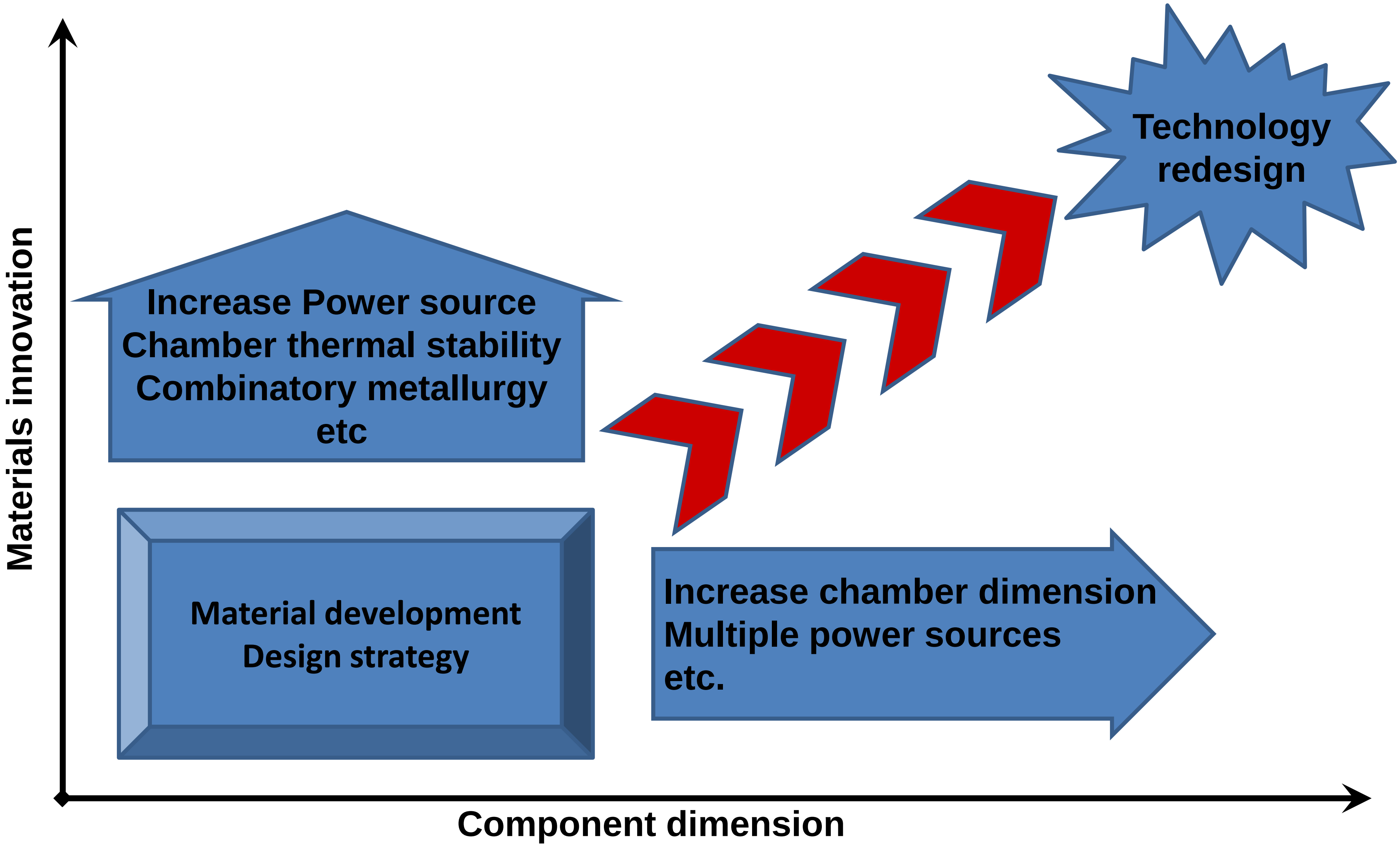
Ti-48Al-2Nb-0.7Cr-0.3Si (at%)

Hollow turbocharger wheel design for weight reduction

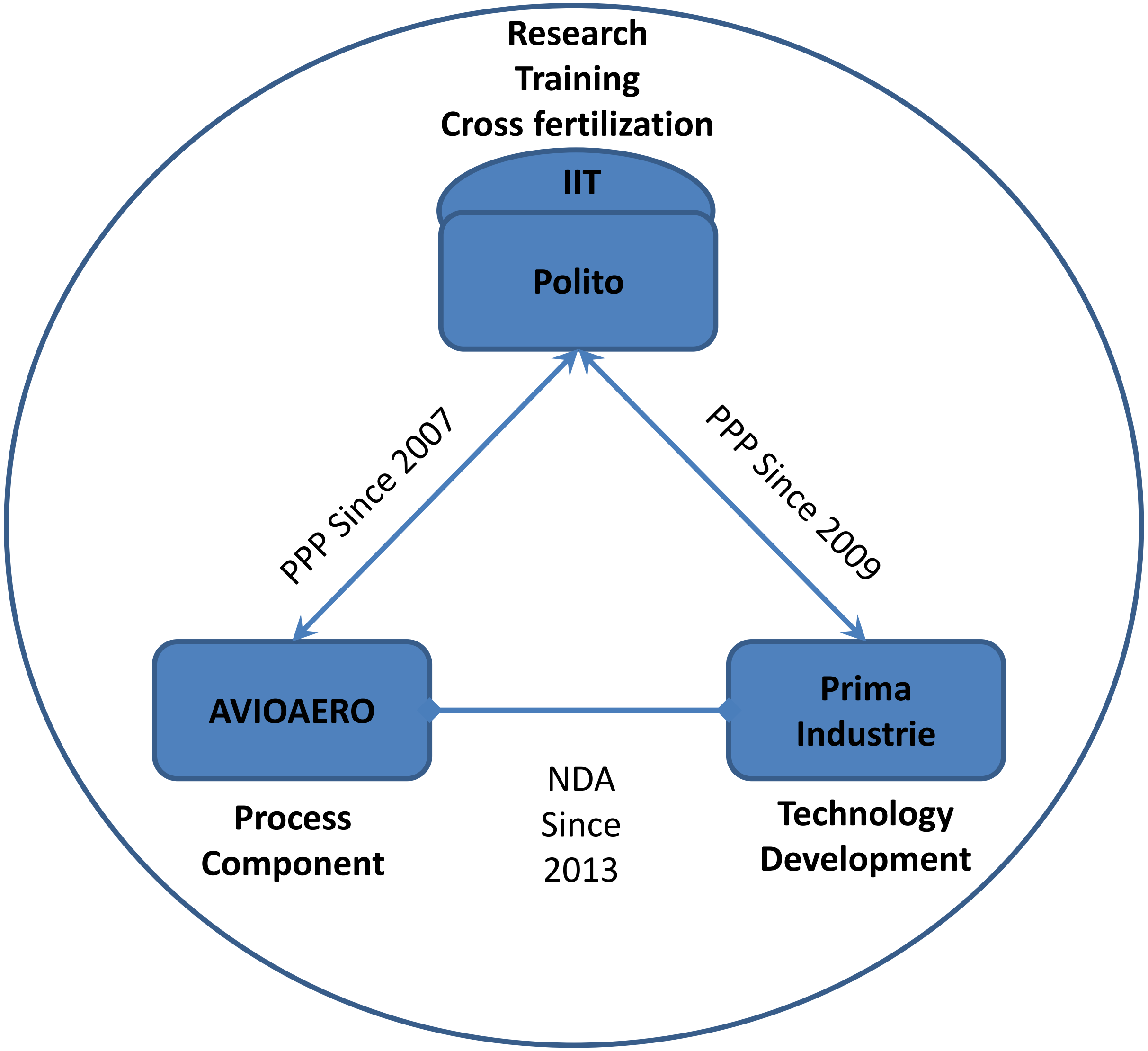



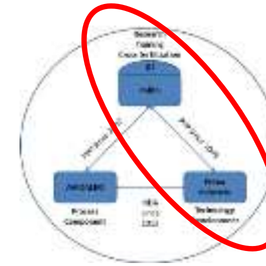
Strategy for the growth



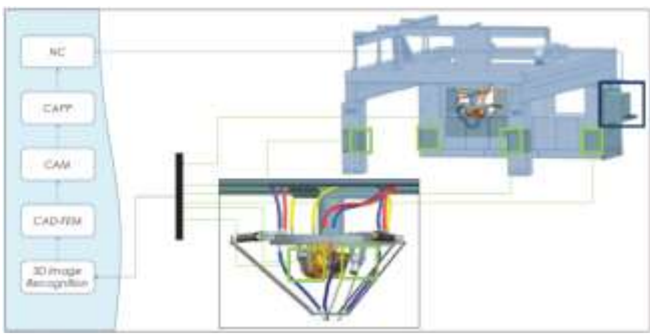
PP Platform


Research
Training
Cross fertilization
IIT
Polito
PPP Since 2007
PPP Since 2009
AVIOAERO
Prima
Industrie
Process
Component
NDA
Since
2013
Technology
Development

BOREALIS



Borealis general objective is to exploit a decade of advanced R&D results in mechatronics and laser processing to demonstrate a novel machine that will produce, at unprecedented throughput (up to 2000 cm3/h) and efficiency (40% energy and 75% material saving), in true net shape (no final machining needed), with closed loop controlled and certified quality (zero faulty parts delivered), large (up to 4.5 m) and complex (in geometry, functionality, composition) products.



- Total Budget: 8150K€
- Polito Budget: 400k€
- Polito activity: Materials and machine requirement, Material characterization

AM in a broader sense

Additive Manufacturing:
broad term → include many technologies

Polito and CSHR@Polito Know-how developed on the entire additive manufacturing process chain, comprising the development, application and implementation of additive manufacturing methods and processes

IMAGINE TO CREATE A NEW MACHINE for..

BOREALIS

To redesign the designer....

Structural founding opportunity

POLITO and IIT are officially involved in
Metallurgy EUROPE - EUREKA

WORK PROGRAMS in H2020 INVOLVING
ADDITIVE MANUFACTURING

Future and Emerging Technologies (FET)

Enabling and industrial technologies (LEIT)

Information and Communication Technologies

Nanotechnologies, Advanced Materials (NMP, FoF),

Biotechnology and Advanced Manufacturing and Processing

Space

Innovation in small and medium-sized enterprises

Smart, green and integrated transport

Kic - EIT

Projects

GREAT 2020 – GReen Engine for Air Traffic 2020 – Regional project (2009-2012).

ProTiAl – Developing of a new concept for optimal Production and machining of aerospace components in TiAl (2009-2012).

AMAZE – Additive Manufacturing Aiming Towards Zero Waste and Efficient Production of High-Tech Metal Products – UE Project, VII FP (2012-2015).

E-BRAKE – Demonstration of breakthrough sub-systems enabling high overall pressure ratio engine – UE Project, VII FP (2012-2015).

TiAl Charger – Titanium Aluminide Turbochargers – Improved Fuel Economy, Reduced Emissions – UE Capacities Project, VII FP (2012 – 2014).

EXOMET – Physical processing of molten light alloys under the influence of external fields – UE Large-scale integrating collaborative project, VII FP (2012-2015).

HELMET – Integrated High-Temperature Electrolysis and Methanation for Effective Power to Gas Conversion - New generation of high temperature electrolyser, UE Project, VII FP (2014-2016).

BOREALIS - the 3A energy class Flexible Machine for the new Additive and Subtractive Manufacturing on next generation of complex 3D metal parts – UE Horizon2020 Project (2015-2018).

GETREADY - HiGh spEed TuRbinE cAsing produced by powDer HIP technologY – UE JTI Cleansky (2014-2015)

GREAT 2020 phase 2– GReen Engine for Air Traffic 2020 – Regional project (2009-2012).

Cluster Aerospazio – Greening the propulsion – National project (2014-2017).

POP3D – Progetto ASI - Validazione del livello di maturità tecnologica di un sistema di fabbricazione additiva polimerica in microgravità per utilizzo a bordo della Stazione Spaziale Internazionale (2014-2016).

Several new proposal focused on AM tech under evaluation (Redemption, Ramlight, Lotsize1, Made in Nephos, Optimus, Levante).

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