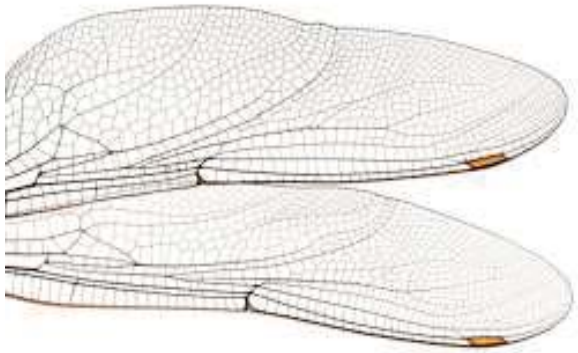
Dragonfly

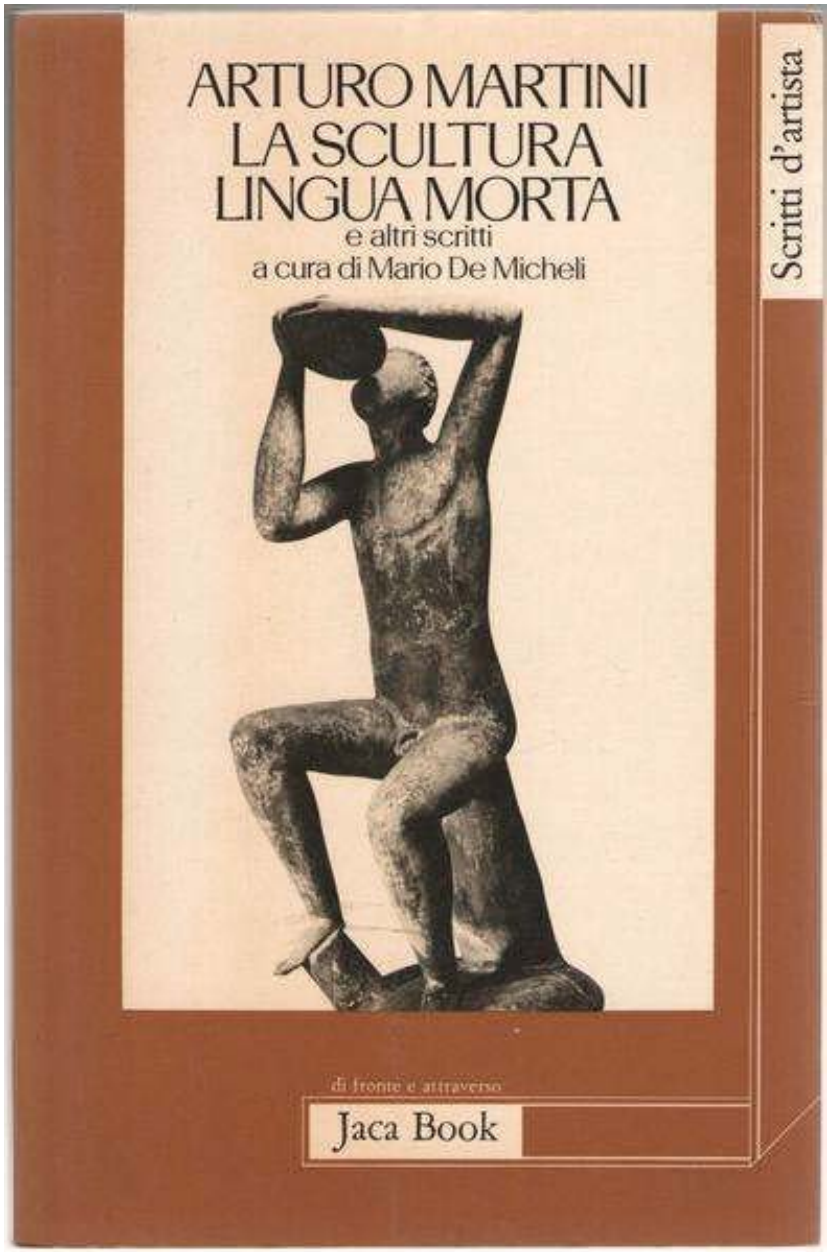


Esperienze economico-gestionali nell'adozione delle tecnologie additive per la produzione seriale di parti metalliche

Torino, 10 Marzo 2016

Claudio Giarda
President & CEO Dragonfly

Michelangelo vs Donatello: Excess vs Essential, subtractive vs additive



ARTURO MARTINI *– «We are here in the presence of an indefinable something but, at the same time, of extremely precise, just like the relationship between the weight and the volume of a body; except that here it is to perceive the specific weight of a work 'art, not the material it's made! How then we will calculate the absolute weight, for example, the bronze David of Donatello and Michelangelo marble one? We do not calculate at all, but we can measure the greater or lesser path, and thus the greater and lesser effort required to get to their absolute weight taking into account the starting point of their authors."*

Dragonfly

Industrial 3D printing enabler

We support Additive Manufacturing adoption in large organizations.
Dragonfly is an Innovative Start-up established 15th April 2015
We are going to offer "Manufacturing as a Service" to our customers

INDUSTRIAL 3D PRINTING OFFERING

Consulting
evaluating & enabling AM adoption

AMALFI
Additive Manufacturing Assessment for Lean and Fast Introduction

Design & Engineering
finding new ways for new products engineering and design

Solutions
end-to-end system integration to embrace industrial 3D printing

OPTOMEC

Production & Prototyping
transforming ideas in real products

CIRA
Centro Italiano Ricerche Aerospaziali

CSM
Centro Sviluppo Materiali

MBDA
MISSILE SYSTEMS

FIELDS OF EXPERTISE

Aerospace *Energy* *Automotive* *Mechanics*

Main partners & customers

NIAM *Network for Italian Additive Manufacturing*

ALM Community *Additive Layer Manufacturing*

AIAD ITALIAN INDUSTRIES FEDERATION FOR AEROSPACE, DEFENCE AND SECURITY

AITA ASSOCIAZIONE ITALIANA TECNOLOGIE ADDITIVE

MBDA MISSILE SYSTEMS

EOS

OPTOMEC Additive Manufacturing Systems — from Nano to MACRO™

NANOPROM

WASS A Finmeccanica Company

THALES

ANSALDO ENERGIA

elt ELETTRONICA mind is the first defence

CIRA Centro Italiano Ricerche Aerospaziali

CSM Centro Sviluppo Materiali materials, technology & innovation

Top F1 Racing Team

Università:
Federico Secondo
La Sapienza
Università di Brescia

Agile, light and fast

Partnership: our Agility & Partners Power

Dragonfly Partnership principle:

be agile light and fast leveraging Partners capabilities,

such as Industrial, market, complementary competences.

Dragonfly partnership with CIRA – Italian Aerospace Research Centre

NIAM

Italian Network for Additive Manufacturing

Established along with other leading partners in the aerospace, engineering and research (MBDA, CIRA, CSM, FOX BIT) to increase the knowledge of Additive Manufacturing, identified as a major factor of innovation for the Italian aeronautics and space field.

3D Printing Facility

AM engineering know how together with production capacity (DMLS and EBM technologies) for revolutionary air and space craft, innovative systems to reduce environmental impact, increase flight safety, make surveillance more effective…

EOS and ARCAM printers

Test Facilities

PWT – Plasma Wind Tunnel
IWT – Icing Wind Tunnel
GHIBLI Hypersonic Tunnel
PT1 – Transonic Wind Tunnel
LISA – Aerospace Structures Impact Lab

unique test facilities, unmatched anywhere in the world, and air & space flying labs

Production Facility: finite metal parts production

Available Max Shape Size: 400x400x360 mm

EOS 290

EOS 400x4

Incoming planned 2017 - as EOS partner we can print such size today

Available Metal Alloys (powders)

- Stainless Steel 17-4
- Hardenable Stainless Steel 15-5
- CoCrMo Super Alloy
- Ti6Al4V Light Metal
- AlSi10Mg Light Metal
- 18 Mar 300
- Inconel™ 718
- Inconel™ 625
- **Hastelloy X (new)**
- **Scalmalloy (new)**

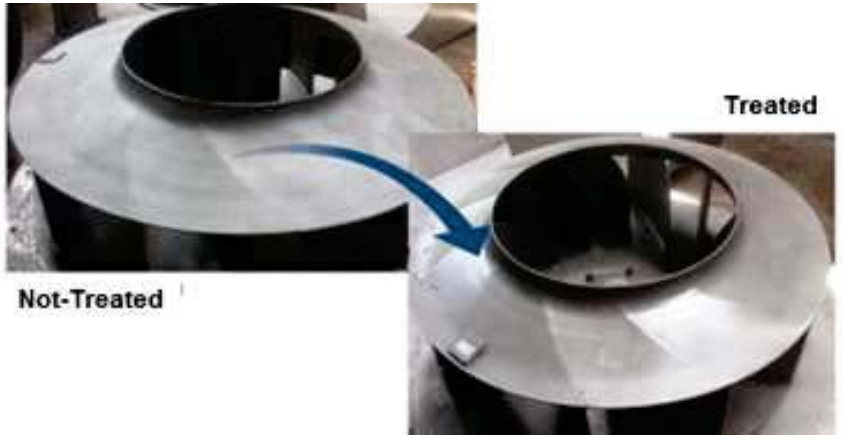
Conventional surface finishing or *"Nanomaterials"*

Nanomaterials for surface finishing

Silicon based nanopolymers coating solutions (10µm thickness) to enhance surface finishing applications.

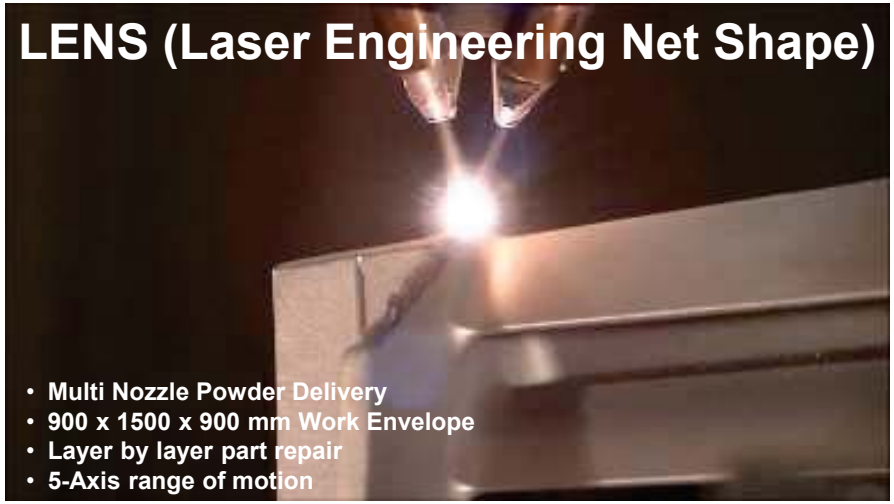
After-Coating Surface Roughness:

- Ra = 0,021 - 0,5 µm
- Corrosion Resistance (2400h)
- High surface Hardness (9h+)

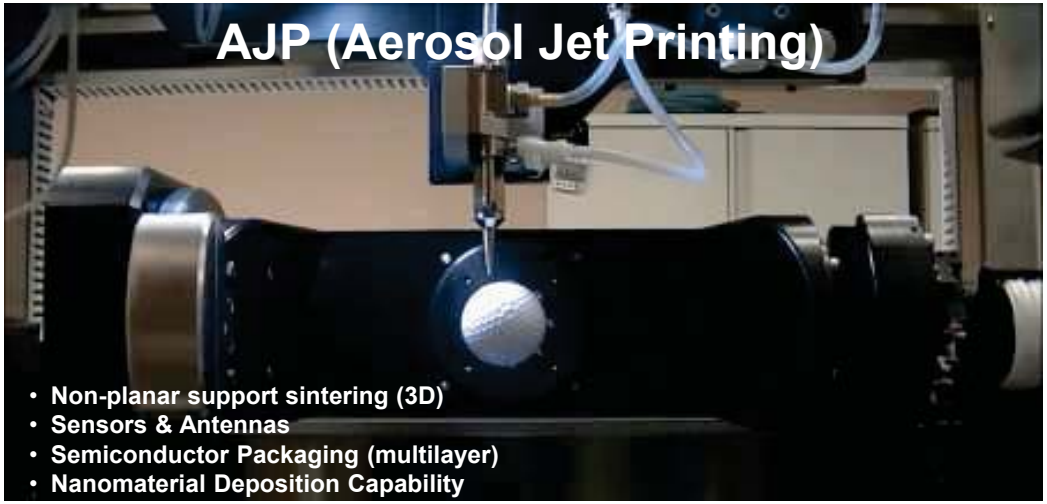


3D Printing Technologies: metals, ceramics & electronics

AM for Metals

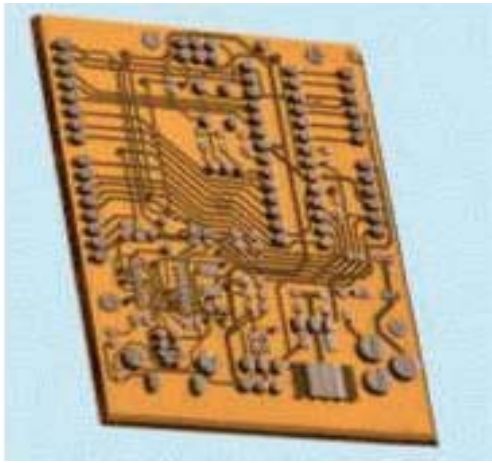


AM for Electronics



AM for Ceramics

AM for Printed Circuit Boards



MBDA – Missile Systems Production Transformation

ALMA – Additive Layer Manufacturing Adoption

February 2014 → **9 months transformation experience** → **October 2014**

Consulting

- **BUSINESS CASE** with AMALFI methodology
- **SCOUTING** for AM materials and technologies supply
- Technical and Industrial **CONVERSION PLAN**

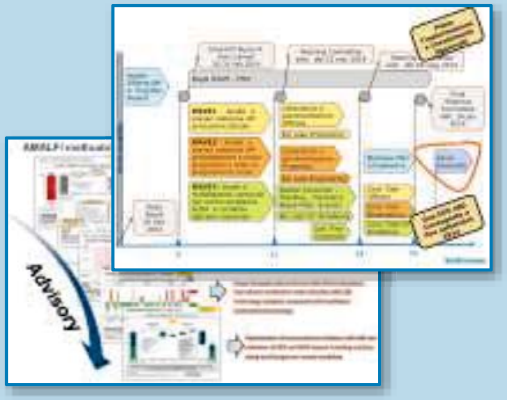
Engineering

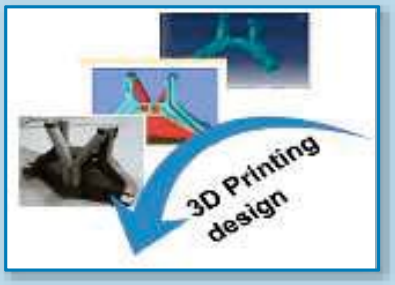
- **FEASIBILITY STUDY** and Experimental Prototyping
- **DESIGN** of mechanical parts for AM production
- **INDUSTRIALIZATION** and qualification of parts for serial production

Solutions

- **SITE PREPARATION** of production areas for 3D printing (safety & security)
- **MACHINES INSTALLATION (EOS M280 - DMLS)** and start up
- Best practices **COACHING** and "on site" training

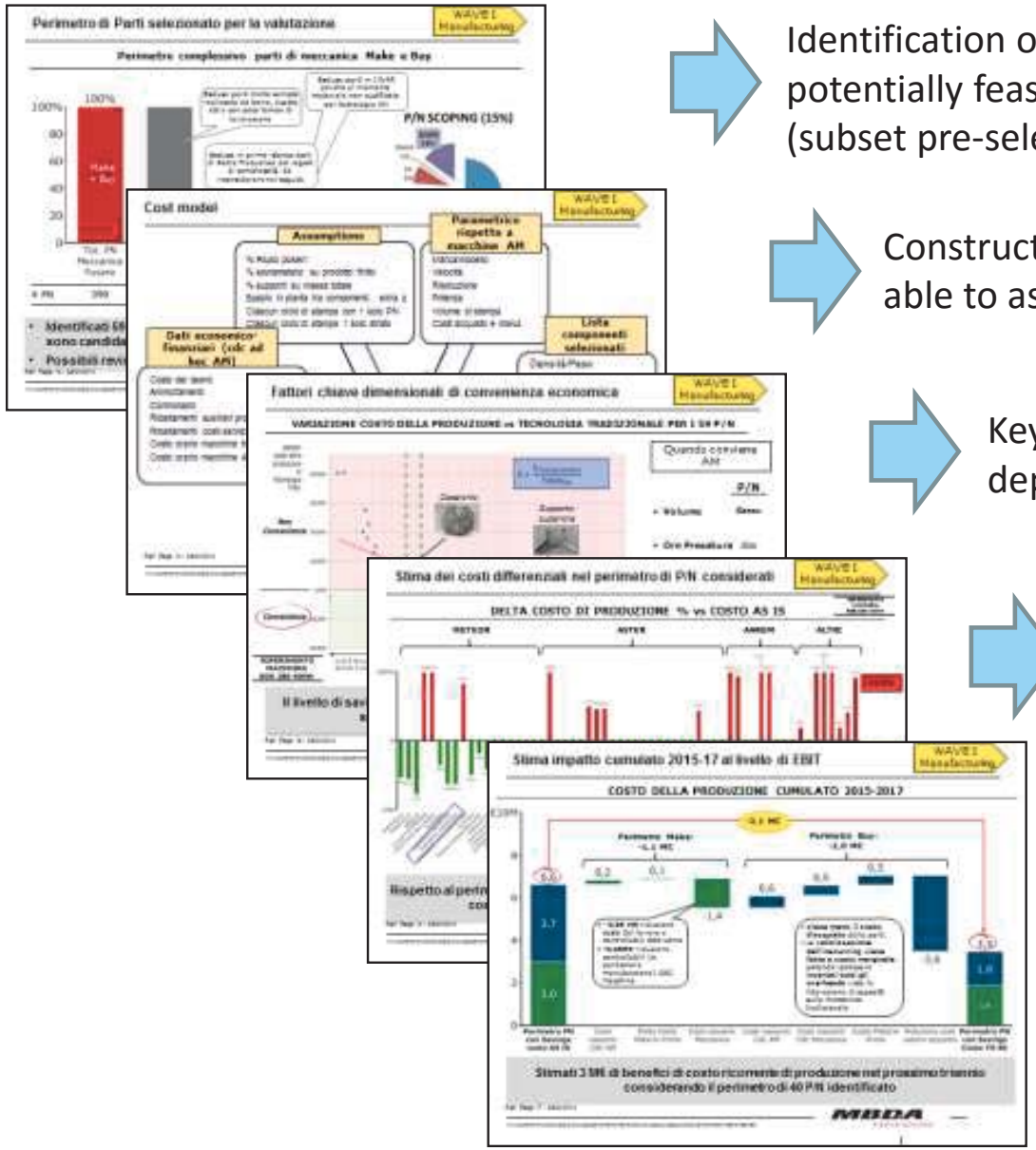
ALMA execution: AM process certification& production





seamless process for AM adoption

AMALFI methodology:
Additive Manufacturing Assessment for Lean and Fast Introduction



Identification of current manufactured Part Numbers potentially feasible and potentially convenient in AM (subset pre-selection from the complete PN list)

Construction of an integrated technical-economic model able to assess AM cost impacts vs traditional technologies

Key factors and correlations for economic benefits depending on PN and machines characteristics

Real Example: About 40 out of the 59 Part Numbers have shown production costs reduction with AM Technology adoption compared with traditional (subtractive) technology

Optimization of new production balance with AM and valuation of EBIT and FOCF impact including machine sizing and changes on current workshop

Dragonfly

Material & 3D Printing Costs

Dragonfly's analysis over 1.000 parts per material category

Metal Additive Manufacturing: Unit Production Costs

The material cost has low impact over the Unit Production Cost, while the Additive Manufacturing production process is the main cost component.

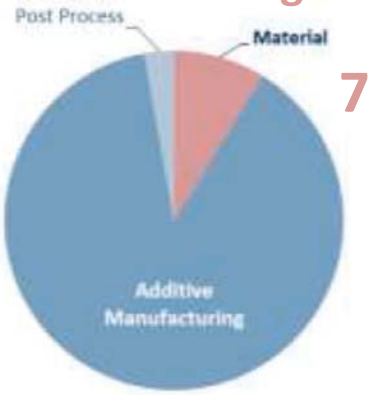
Average Unit Material Cost per material category:

Stainless Steel 17/4

Powder cost: 70 €/Kg

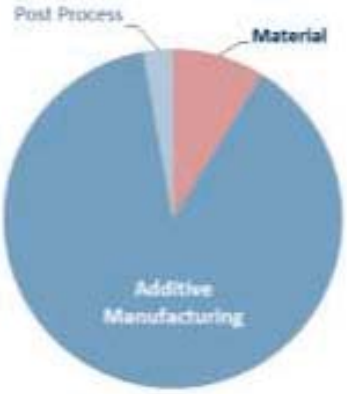
6-10%

AlSi10Mg



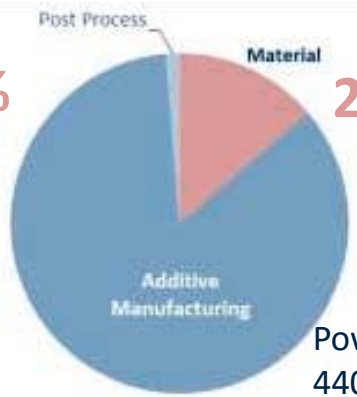
7-12%

Inconel 718



11-16%

TiAl4V



20-30%

Powder cost: 440 €/Kg

Powders

- Powder transformed
- Wasted Powder

From 5% to 30%

Additive Manufacturing

- Set Up
- Laser Sintering
- Recoating
- Set Down

From 75% to 90%

Post Process

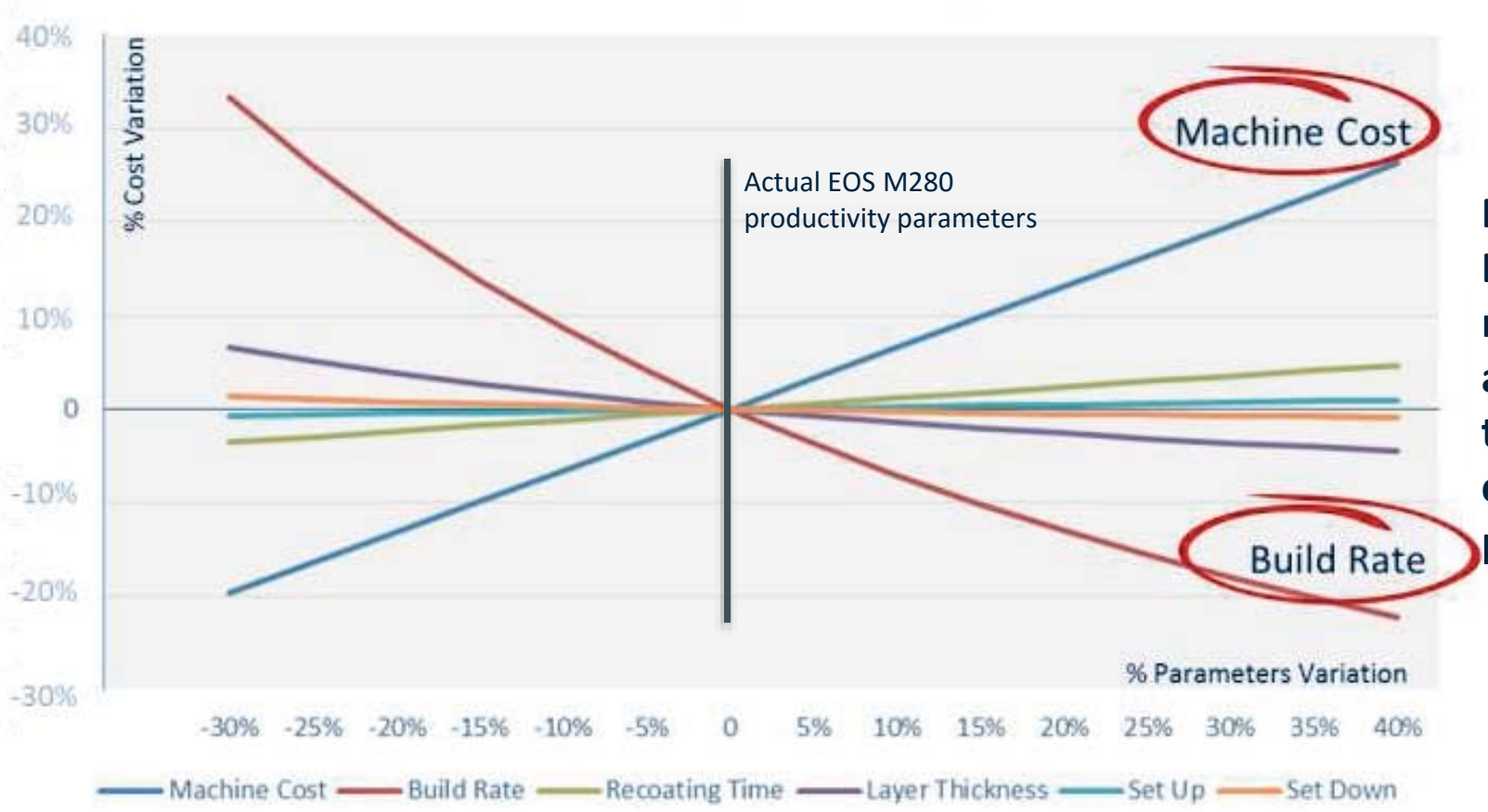
- Powders Sieving
- Heat treatment
- Support Removal

From 1% to 5%

Key machine parameters for productivity & production costs

Slow production process & high machine cost

Unit Production Cost Sensitivity from changes in machines parameters



Actual Machine Price (DMLS technology):

starting from 550 K€

Machine Cost and Build Rate are the main parameter that are actually limiting the AM technology convenience in production

Actual Build Rate (AlSi10Mg):

circa 5,4 mm^3/s

Dragonfly simulation on 1.000 PN (AlSi10Mg) – EOS M280 productivity parameters

MBDA Certification for serial production (Q1 2016)

Quality Assurance campaign for serial production

November 2014 → Q1 2016

1 Material (powders)

- **VALIDATION TESTING** of both New and Used powder
- Powder **RECICLABILITY**
- Powder **STORAGE** arrangement & **HANDLING** procedures

≈ 200 tests

- ✓ Chemical Analysis
- ✓ Granulometry
- ✓ Moisture content
- ✓ ....
- ✓ Shape
- ✓ Density
- ✓ Flowability
- ✓ ....

2 Process (technology)

- Process **ISOTROPY** assessment
- **MATERIAL CHARACTERIZATION**

≈ 800 tests

- ✓ Tensile
- ✓ Density
- ✓ Hardness
- ✓ ....
- ✓ Fatigue
- ✓ Corrosion Resistance
- ✓ ....

3 Product (performance)

- **PART testing**
- **ASSEMBLY testing**

≈ 100 tests

- ✓ Dimensiona l test (CMM)
- ✓ Rx
- ✓ Die Penetrant
- ✓ ....
- ✓ Vibration
- ✓ Shock
- ✓ ....

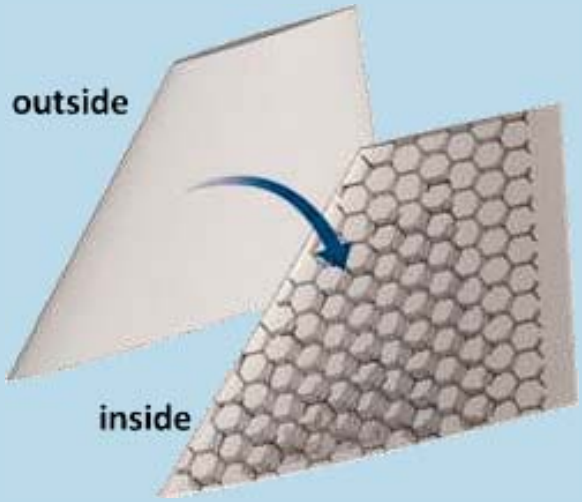
More than 1.000 tests

Recent and concrete experiences in MBDA

Wing LIGHTWEIGHTING

Replacing the Wing full body with optimizable lattice structures, while leaving a solid skin on the outside and meeting the required mechanical requirements.

Target: 60% weight reduction



Starting lattice topology:

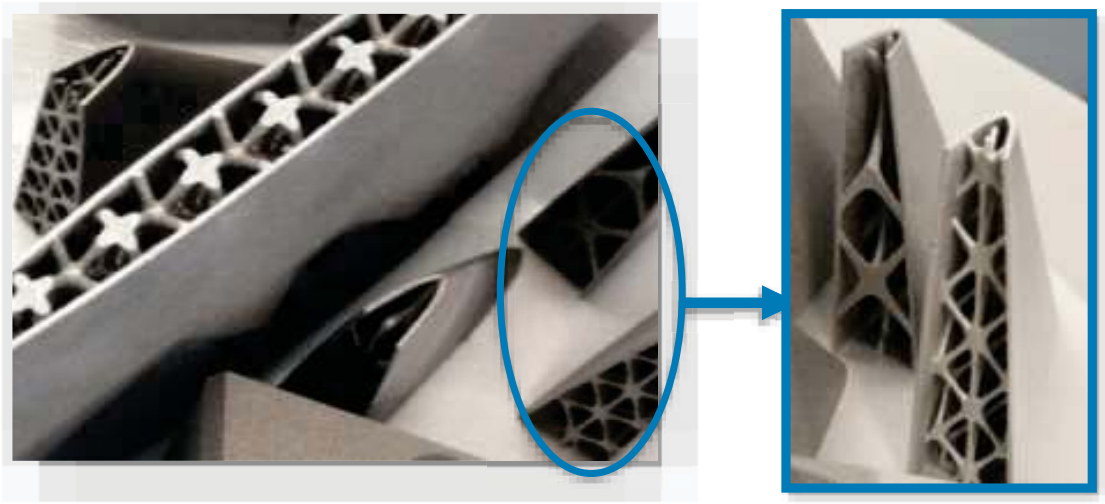
A kind of lattice structure has been choosed (Star), which satisfy the requirements of being simmetrycal and AM friendly (over 45° angles)

Material:

Aluminum alloy AlSi10Mg has been chosen to manufacture the wing, being light and adherent to aerodynamic and stress requirements

Optimization:

The lattice will be optimized to deal with the worst case scenario of duty (applied Pressure and Force).



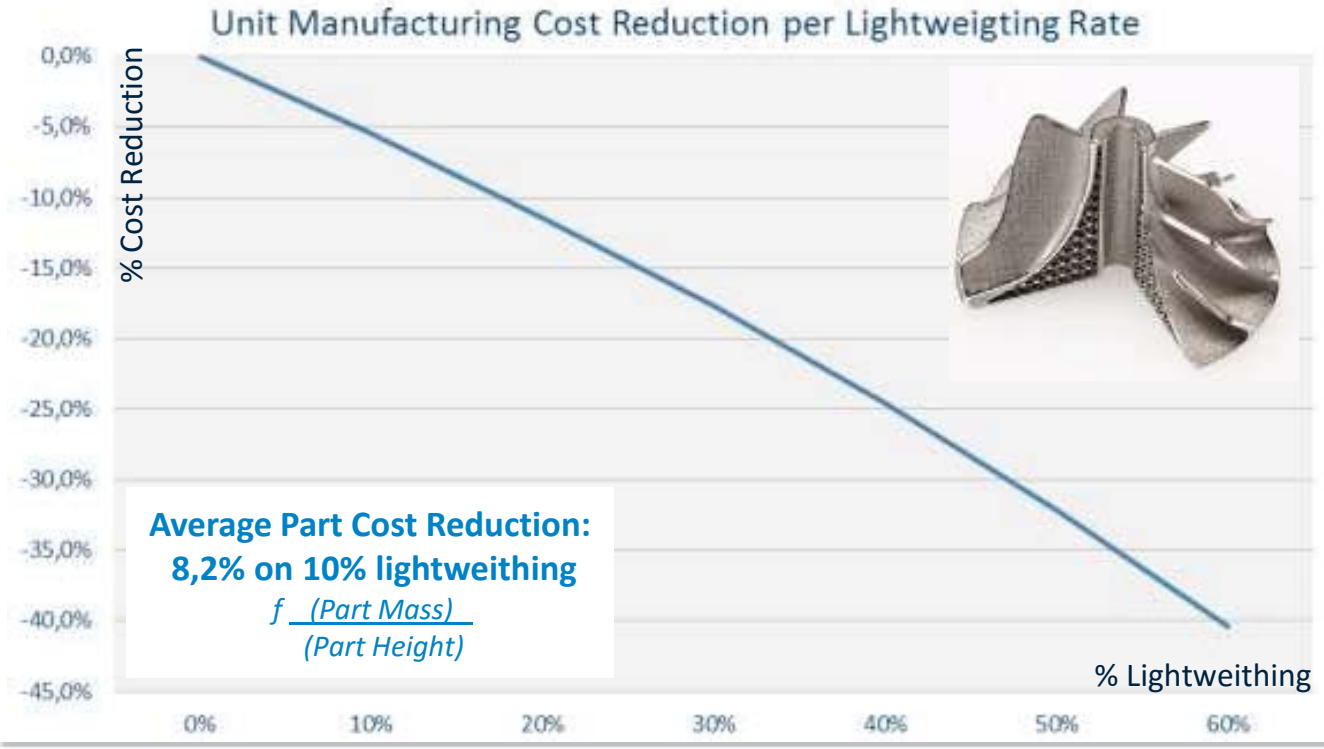
First tests of lattice structures performed

Product Light-weighting & AM Production Cost

Less product weight, less production costs

Automatically generated by AM technology

Lightweiting Direct Cost Reduction
Lightweigthed Mass * (C_{Powder} + $C_{Build\ Rate}$)



<u>Analysis on different 1.000 parts</u>

- Shape: different shapes per each part (both complex and easy);
- Box Dimension: min 10x10x10 mm; max 240X240x240 mm;
- Material: Aluminum alloy (AlSi10Mg);
- Production Parameter:
  - Technology: DMLS - EOS M290;
  - Volume production: from 50 to 200 parts per year;
- 3D Job main assumption:
  - Job orientation: 90° (best productivity rate);
  - Support structures: 5% (on PN mass);
  - Finishing allowance: 2% (on PN mass);
  - Powder waste: 5%.

Dragonfly's experience and evolution strategy

High product change

NO supply chain change

High supply chain change

No product change

"Product Evolution"

Concrete experience: MBDA and Aerospace & Racing

Dragonfly's excellence and business area of strategic development

"Business Model Evolution"

Dragonfly's project: AMO software

Dragonfly is working on the Cloud AM Orchestrator able to manage MRO and Logistics Operations on a full digital supply chain.

"MBDA AM Transformation"

Additive transformation experience: MBDA

"Supply Chain Evolution"

Dragonfly's project: Pop Up Factory in a Shelter

Dragonfly is developing a concept for instant fabrication of parts (AM fast deployment and logistics revolution)

Dragonfly

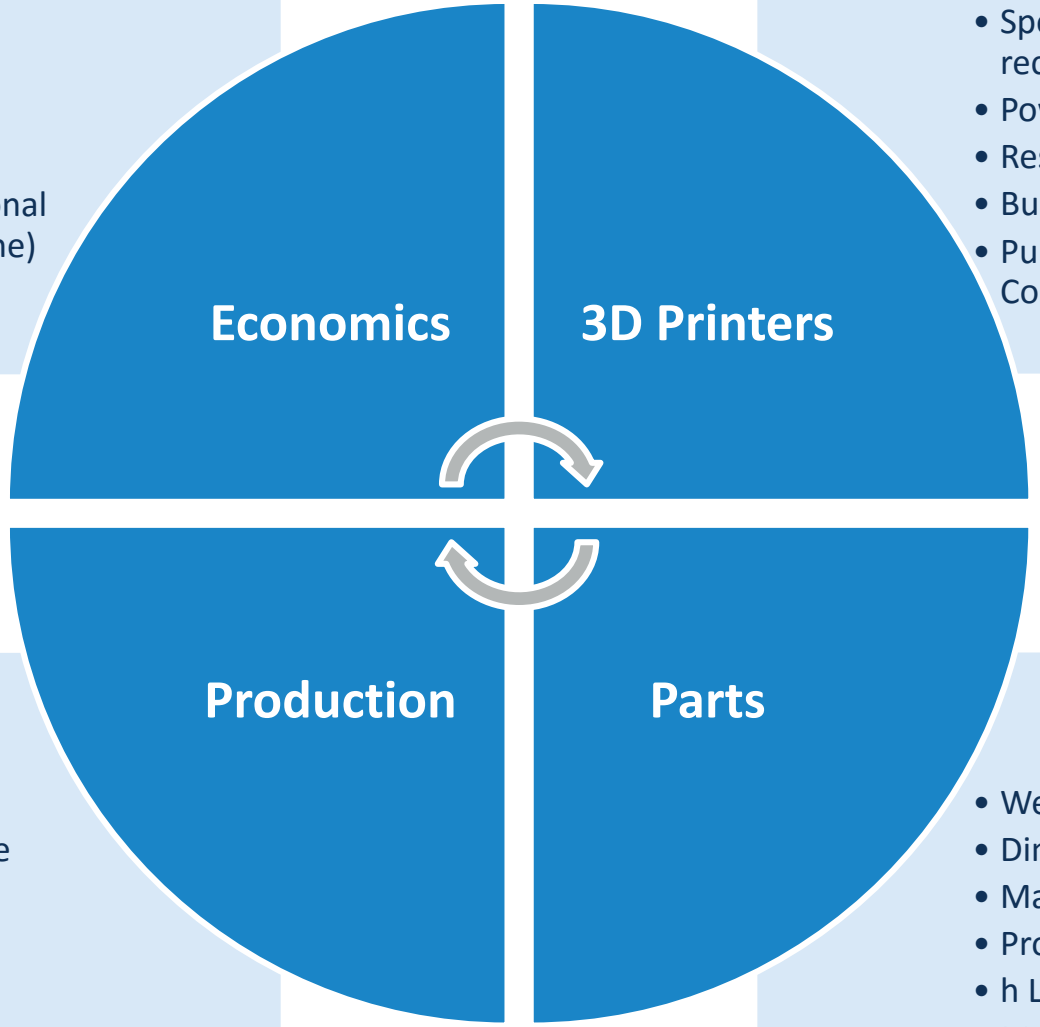
www.dragonfly.am

Claudio Giarda – President & CEO

claudio.giarda@dragonfly.am

AMALFI: Technical-economical model with four parameter families

- Labor Cost
- Depreciations
- Consumables
- Overhead & Back-charged Costs
- Hourly Costs (Traditional vs 3D Printing Machine)



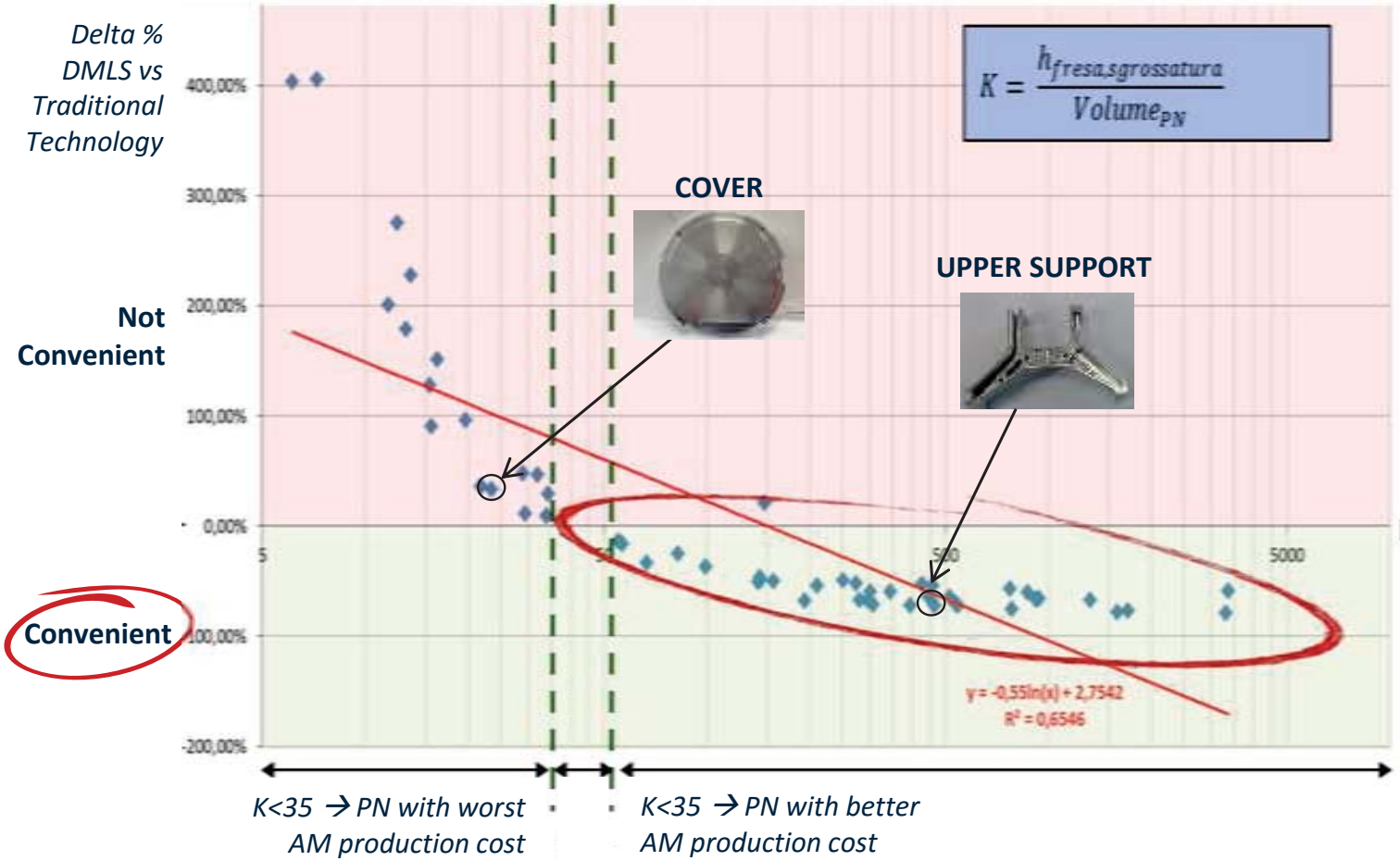
- Producer & Model
- Speed (build rate & recoating)
- Power
- Resolution
- Building Volume
- Purchase & Maintenance Costs

- % Powders Reuse
- % Finishing Allowance
- % Support Structure
- Nesting & Extra z
- N PN per Production Cycle

- Weight / Density
- Dimensions
- Material
- Production Volumes
- h Labor / Machine
- Make / Buy

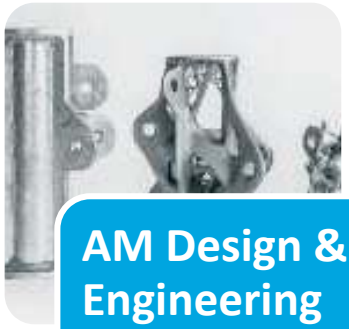
Additive Manufacturing: key convenience factors

Production Cost: DMLS vs Traditional Technology



P/N	
• Volume	*Low*
• Milling Hours	*High*
• Buy to Fly	*High*
• Encumbering	*Low*
• Shape	*Complex*

3D Printing: production process



AM Design & Engineering

- New designing rules
- New software & tools
- Parts redesign & Lightweiting

Industrialization

- Material Tests
- Part Performance

3D Printing Job

- Job preparation
- Support structure

Powders

- Powder transformed
- Wasted Powder

Additive Manufacturing

- Set Up
- Laser Sintering
- Recoating
- Set Down

Post Process

- Powders Sieving
- Support Removal

Stress Release & Test

- Heat treatment
- Test (form, fit & function)

Finishing & Superfinishing

- Milling (CNC)
- Surface treatment

Core 3D Printing production phases