EFFICIENT ADDITIVE MANUFACTURING FOR LARGE HYBRID COMPONENTS

International Conference on Additive Manufacturing

Speaker: José Antonio Dieste

(AITIIP Technological Centre)

EMO Hannover 18-23·9·2017

Hannover (Germany) Sept 21st 2017

cecimo European Association of the Machine Tool Industries

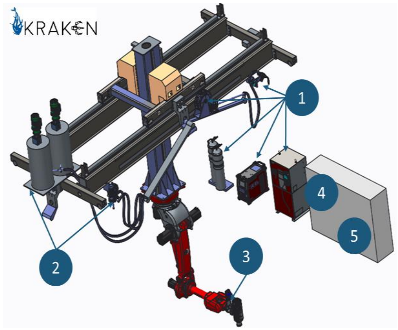
Introduction

Shaping Basic Principles.

Formative shaping: The desired shape is acquired by application of pressure to a body of raw material, examples: forging, bending, casting, injection moulding, the compaction of green bodies in conventional powder metallurgy or ceramic processing, etc.
Subtractive shaping: The desired shape is acquired by selective removal of material, examples: milling, turning, drilling, EDM, etc.
Additive shaping: The desired shape is acquired by successive addition of material.

Additive Manufacturing:
Process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies.

EN ISO/ASTM 52900
"Additive manufacturing — General principles —Terminology"



KRAKEN

Introduction

Additive Manufacturing History.

1981: first patent by Japanese Dr Kodama Rapid prototyping
1987: First SLA-1 machine
1988: first SLS machine by DTM
1990: First EOS Stereos system
1992: FDM patent to Stratasys
1995: Z Corporation obtained an exclusive license from the MIT

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Source: The Fifth Element (1997). Producer: Patrice Ledoux

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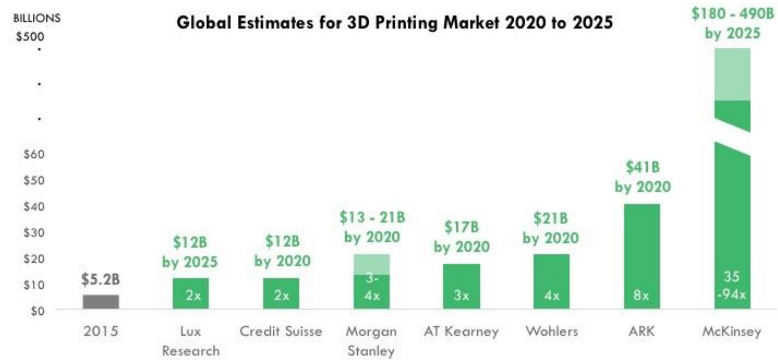
1995: Z Corporation obtained an exclusive license from the MIT
1997: The fifth element.
1999: Engineered organs bring new advances to medicine
2000: a 3D printed working kidney is created
2000: MCP Technologies (an established vacuum casting OEM) introduced the SLM technology
2005: Z Corp. launched Spectrum Z510. It was the first high-definition colour 3D Printer on the market.
2006: An open source project is initiated (Reprap)
2008: The first 3D printed prosthetic leg
2009: FDM patents in the public domain

Introduction

Additive Manufacturing Evolution.



Source: ARK Investment Management LLC

The Global economy is said to be about $80 trillion, and manufacturing accounts for about 16%, which is $12,8 trillion.

At $5,2 billion in 2015, AM represents only 0,041% of all manufacturing.

If AM grows to capture just 5% of the global market, it would become $640 billion.

Wohlers believes that it could someday exceed 5% of the total
McKinsey believes to overpass 1% in 2025

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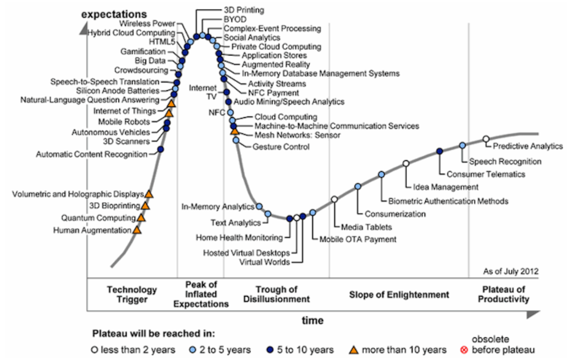
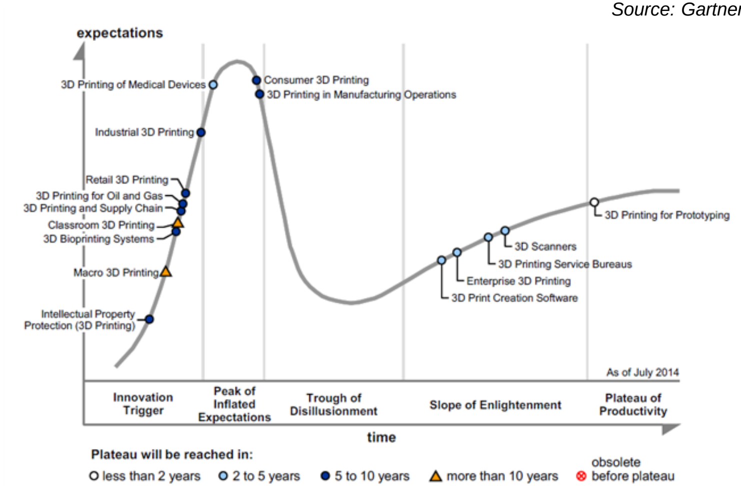
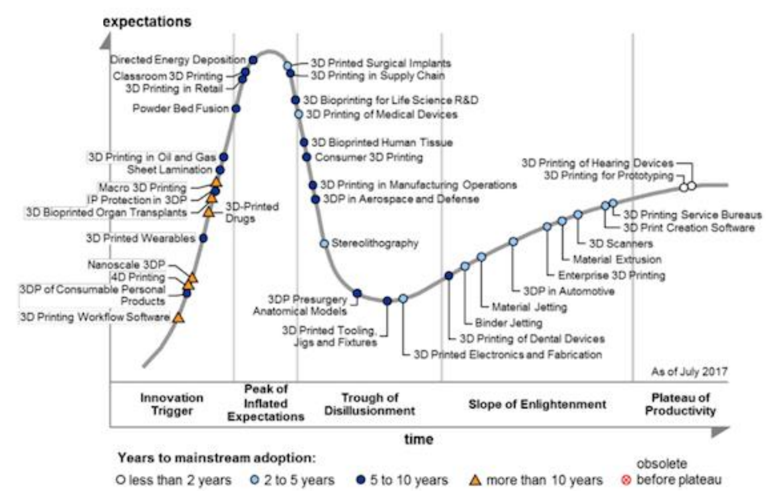
Additive Manufacturing Evolution.



Source: Gartner 2012



Source: Gartner 2014



Source: Gartner 2017

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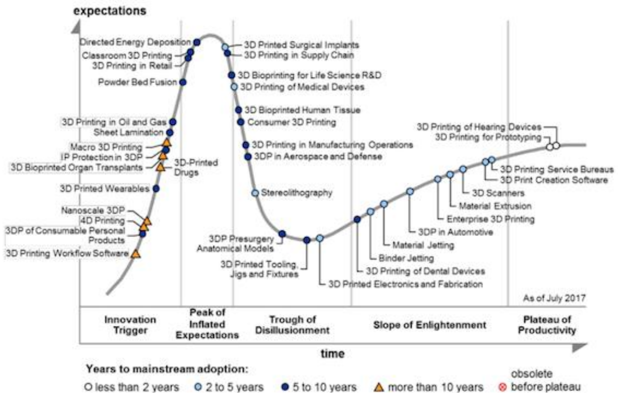
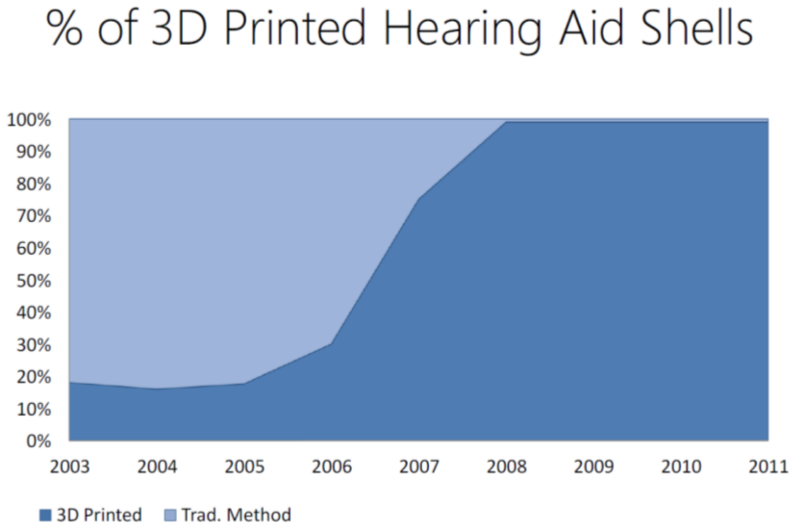
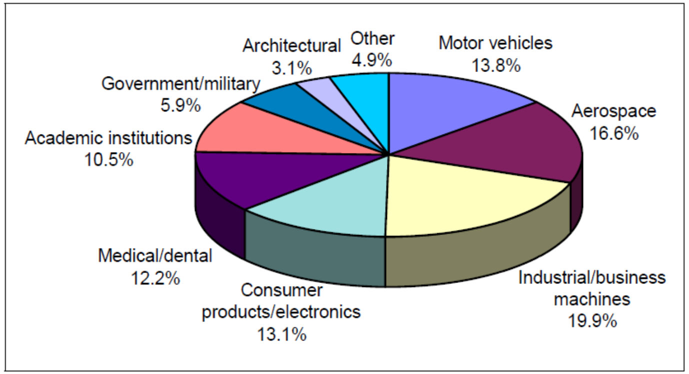


Source: Materialise



Source: Materialise



Source: Wohlers Associates Inc.

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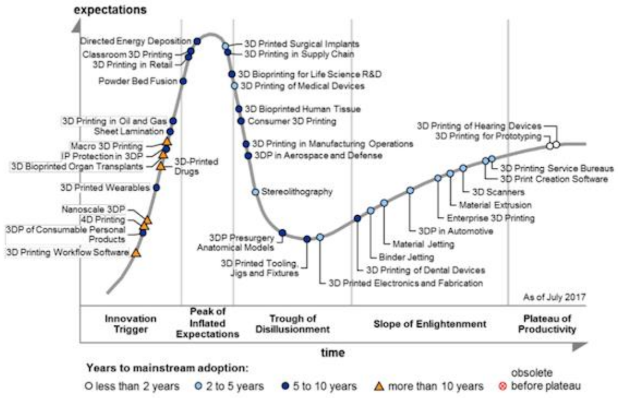
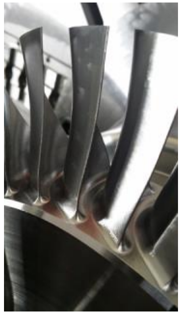
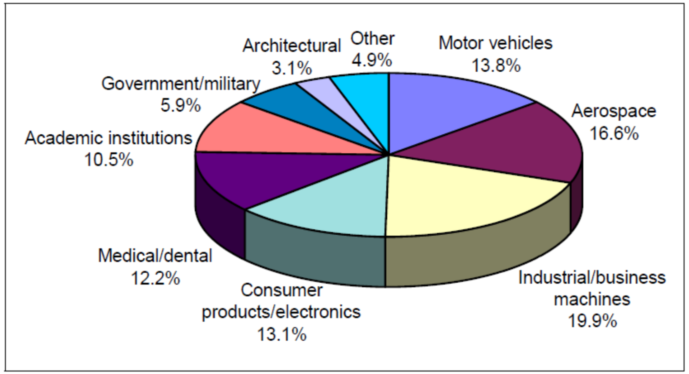
Additive Manufacturing Evolution.







Source: Wohlers Associates Inc.

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Implementation | Consortium

Partners

Aitiip Coordinator Spain	Acciona Partner Spain	Alchemie Partner United Kingdom
Arasol Partner Spain	Autonomous Systems SRL Partner Romania	CECIMO Partner Belgium
Centro Ricerche FIAT (CRF) Partner Italy	CSEM Partner Switzerland	Espace2001 Partner Luxembourg
Leica Geosystems Partner Switzerland	Pininfarina Partner Italy	Teamnet Group Partner Romania
TWI Partner United Kingdom	VBC Partner Greece	Vero Software Partner United Kingdom

Formed by **15 partners**:

- 6 large companies,
- 5 SMEs,
- 3 research organizations and
- 1 industry association

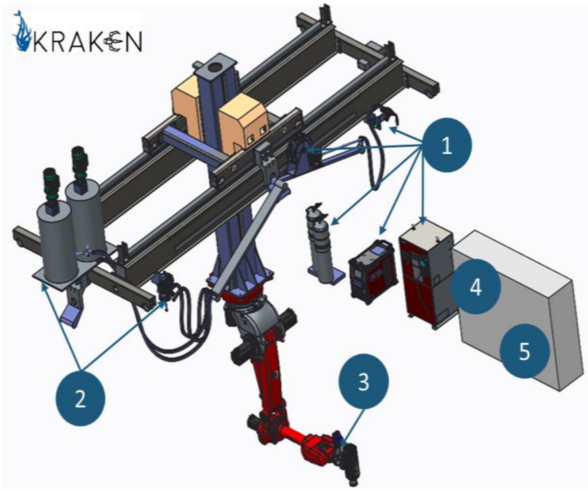
Strong scientific, technical, technological and manufacturing skills

This project has received funding from the *Horizon 2020 research and innovation programme* under grant agreement No **723759**

Concept | Objectives

KRAKEN will focus on the following challenges:

1. High effective additive system for large metal parts by developing AMHT (Additive Metal Hybrid Technology) for aluminum grades.
2. New polymer-based additive manufacturing system for large parts → formulating new materials.
3. Optimize removal rates and accuracy → new tools and high speed milling concepts.
4. Adapt the behavior of the machine to the specific material or situation → sensors + robotic controller.
5. New algorithms in CAM systems for hybrid manufacturing, including planar horizontal layer strategies, and new direct 3D free-form approaches.
6. Full integration and validation of the all-in-one KRAKEN machine → Full demonstration in 3 real case industrial scenarios.
7. Definition of commercial pathways and strategies (standardization requirements, market analysis, users acceptance, green procurement procedures, regulatory issues) for the implementation and exploitation of KRAKEN.
8. Demonstration & quantification of savings on raw materials and energy due to the efficiency of the novel hybrid manufacturing processes.
9. Promotion of the development of EU policies and standards.

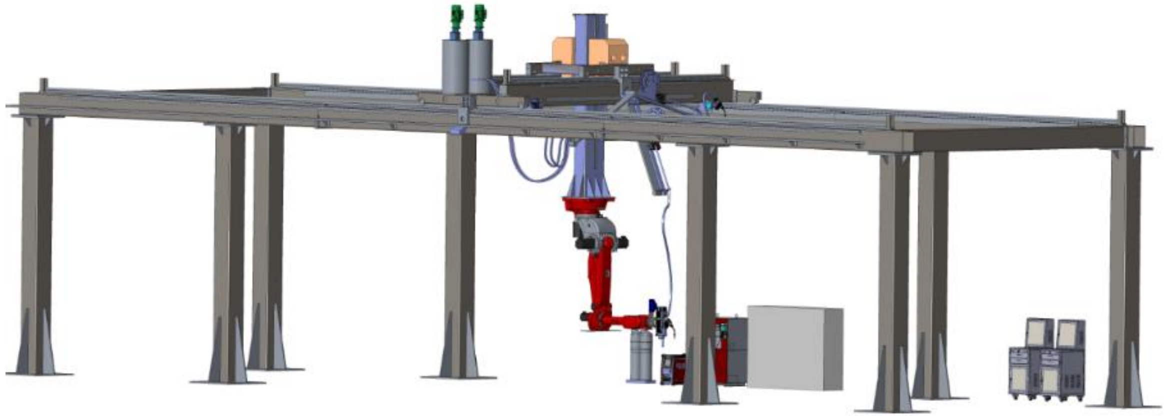


Cross Cutting | Exploitation and Impact

- Stimulate the creation of **jobs** in Europe through the implementation and replication of KRAKEN in the short/medium term
- Promote the development of EU **policies and standards** contributing to the acceptance of the production approach derived from KRAKEN
- Facilitate **training** of high-skilled workers concerning hybrid manufacturing
- **Disseminate** the concept and benefits of KRAKEN among experts and general public
- Identify business models and plans to pave the way for the commercial **exploitation of the products** and services derived from the project (i.e. KRAKEN Machine, accuracy based machine controllers, material hybrid AM, HM CAM, high added value manufacturing services, etc.)
- **Direct benefit for the partners**, RD companies, technology providers, service SMEs, Industry Associations, large companies to implement project's results on the shop floor.

New developments

Main research fields in KRAKEN:



Multimaterial 3D printing

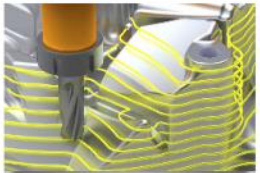
Hybrid manufacturing with aluminium grades, up to 10kg/h deposition rates using Additive Metal Hybrid Technology + Hybrid manufacturing with new polymer-based materials (thermoset Epoxy and PUR resins) reaching 180kg/h

Subtractive manufacturing

Fast and precise milling for large parts based on climb-up methodology specially designed for the planar layer-by-layer and direct 3d freeform production strategies.

Robotics

An assembly robot on a crane able to move with 6+3 DoF, covering a large workspace (20x6x5 meters).



CAM systems

Create new CAM algorithms for hybrid manufacturing, including planar horizontal layer strategies and new direct 3D free form approaches.

Real time control

Real-time control of tool position, force, speed, temperature, and shape deviations.

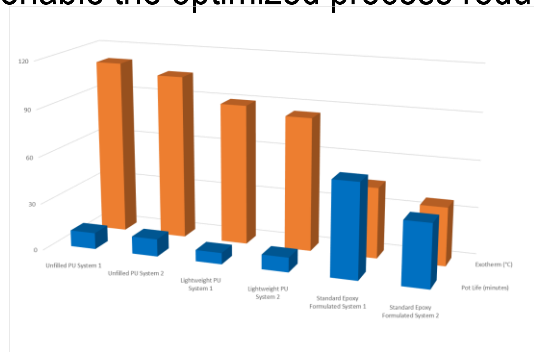
Process Development (Additive Polymer)

Multimaterial 3D printing

Hybrid manufacturing with aluminium grades, up to 10kg/h deposition rates using Additive Metal Hybrid Technology + Hybrid manufacturing with new polymer based materials (thermoset Epoxy and PUR resins) reaching 180kg/h

Resin Based High deposition rate 3D printing (AM):

- New 3D printing concept. Based in Thermoset Resin (Epoxy or Polyurethane based)
- New formulations to enable the optimized process reducing exotherm and adjusting pot life for process efficiency.



- 2 components in paste viscosity ranges tuning the formulation to obtain:
  - Dispensing easiness
  - sag resistance
  - Mechanical properties
  - Cure properties
  - Wetting out between layers

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Process Development (Additive Polymer)

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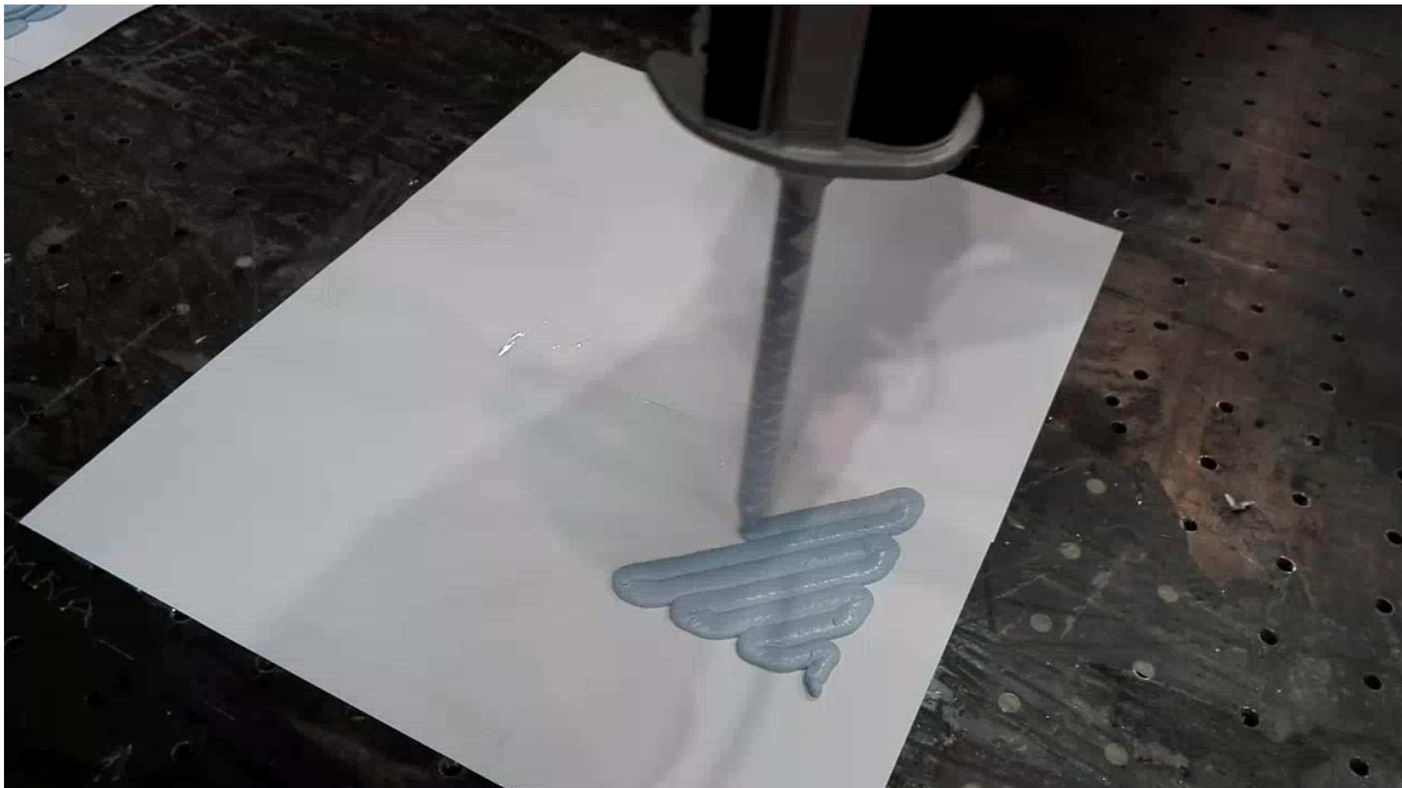

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Process Development (Additive Polymer)

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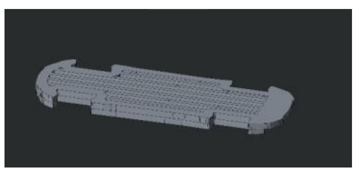
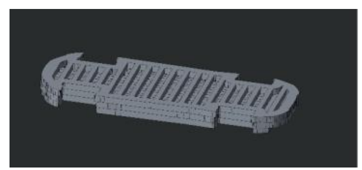
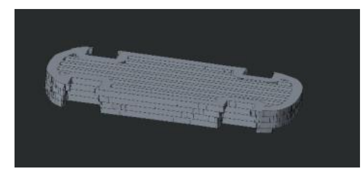
- Upscaling the solution. High deposition rates. Automatic machine. Kraken integrated

- Formulations in different densities to enable good material and support material for the additive manufacturing process

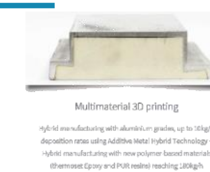






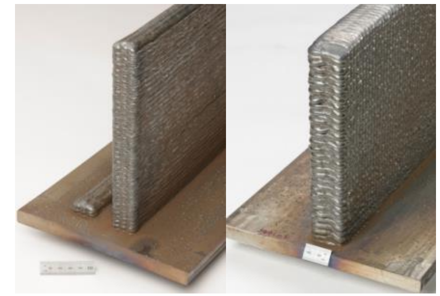
- Optimization of layer thickness, beam width, vertical angle limits, support geometry

Process Development (Additive Metal)



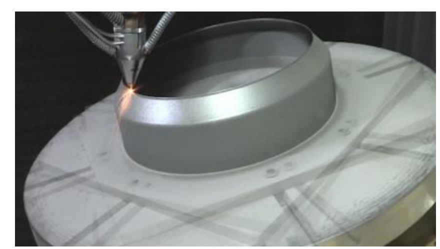
Metal Based. Integration of several technologies in a dedicated AMHT

- Arc-Wire (high deposition rate, lower accuracy, high heat input, ~100% material utilisation)



- Laser-Wire (medium deposition rate, medium accuracy, medium heat input, ~100% material utilisation)

- Laser-Powder (low deposition rate, high accuracy, low heat input, 60-80% material utilisation)



Source: TWI

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Process Development (Material Hybridization)

Metal-Polymer Hybrid Parts generation

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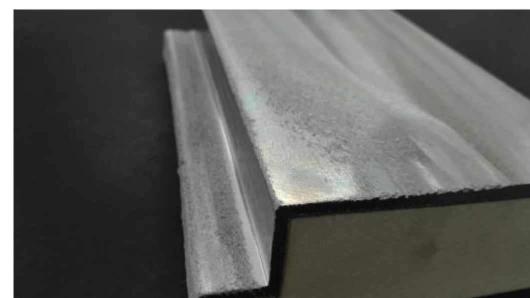
- Polymer on Metal. Formulation of the resin materials to assure a good adhesion to metals

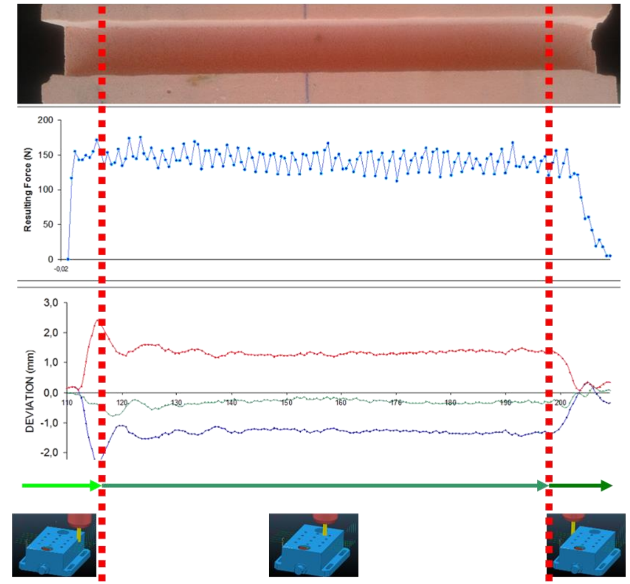
- Metal on Polymer. Creation of an interface layer on the polymer to enable the arc based process.

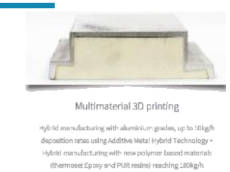


Process Development (Subtractive)

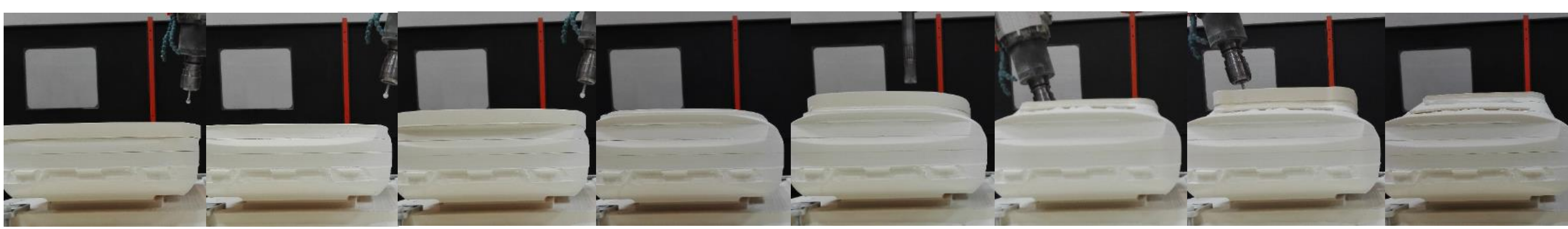
Net Shape

- Cutting forces, flexibility of the system.
  For Resins and Metals





- Hybrid strategies (Additive + Subtractive)



Process Development (Subtractive)

Multimaterial 3D printing

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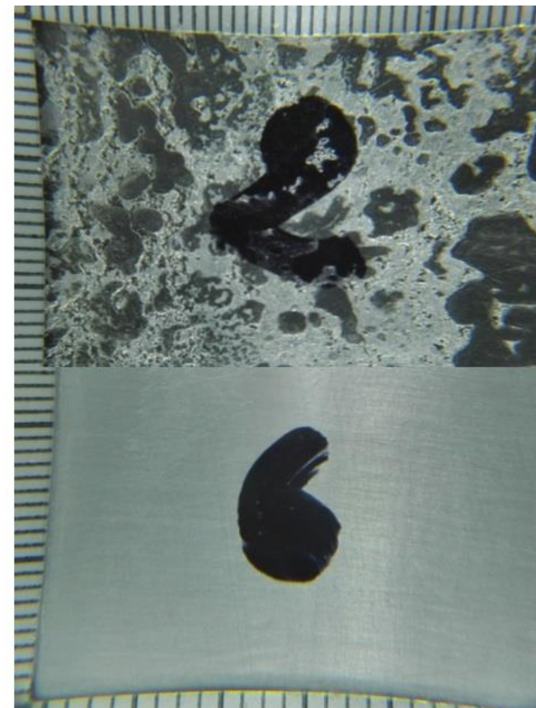
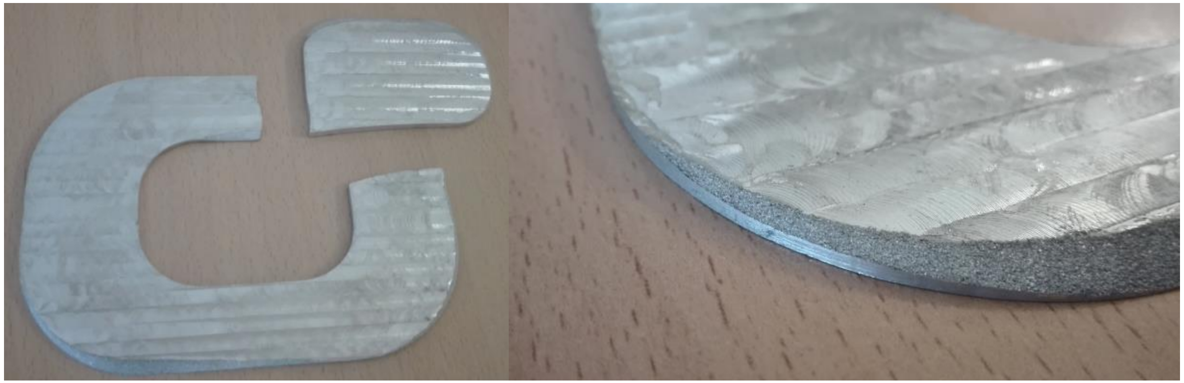
High Quality Surface

- Development of Finishing methodologies to reduce Ra



Process Hybridization

- METALLIZATION+MILLING



- WAAM+RESIN EXTRUSION+MILLING

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- RESIN EXTRUSION+METALLIZATION+MILLING

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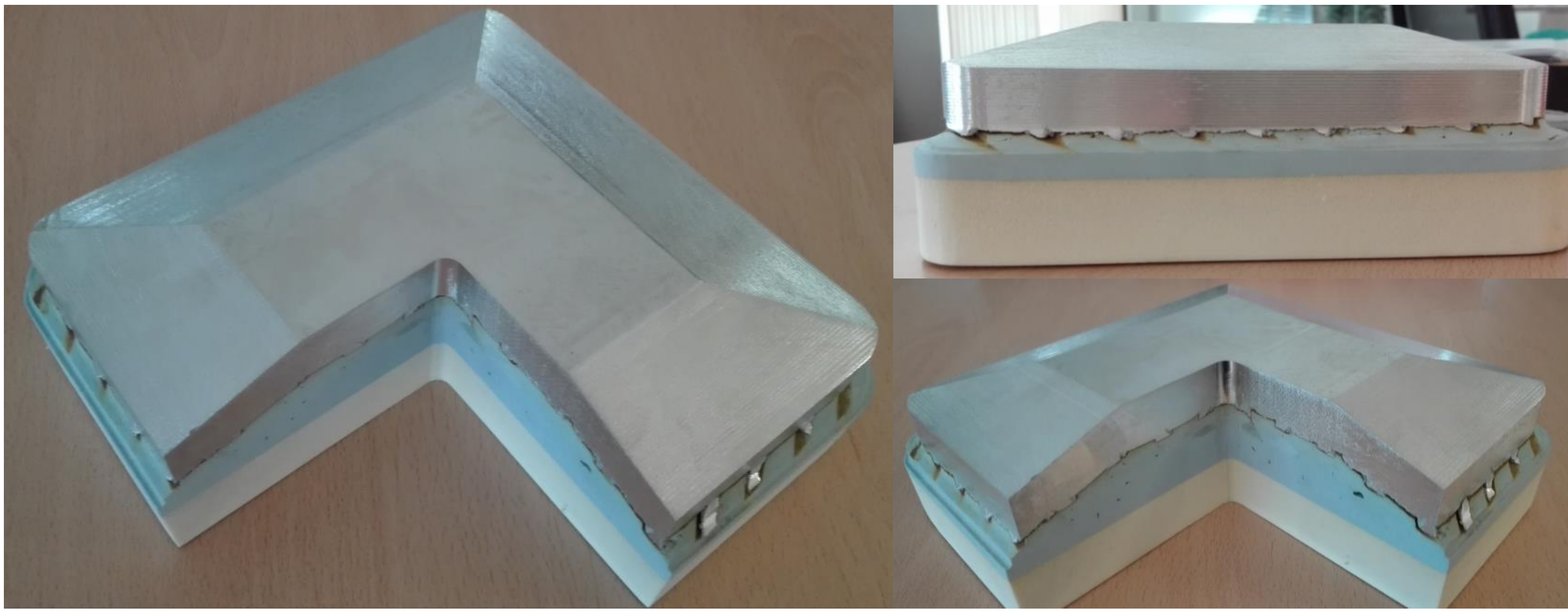
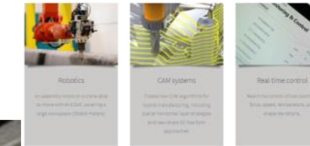
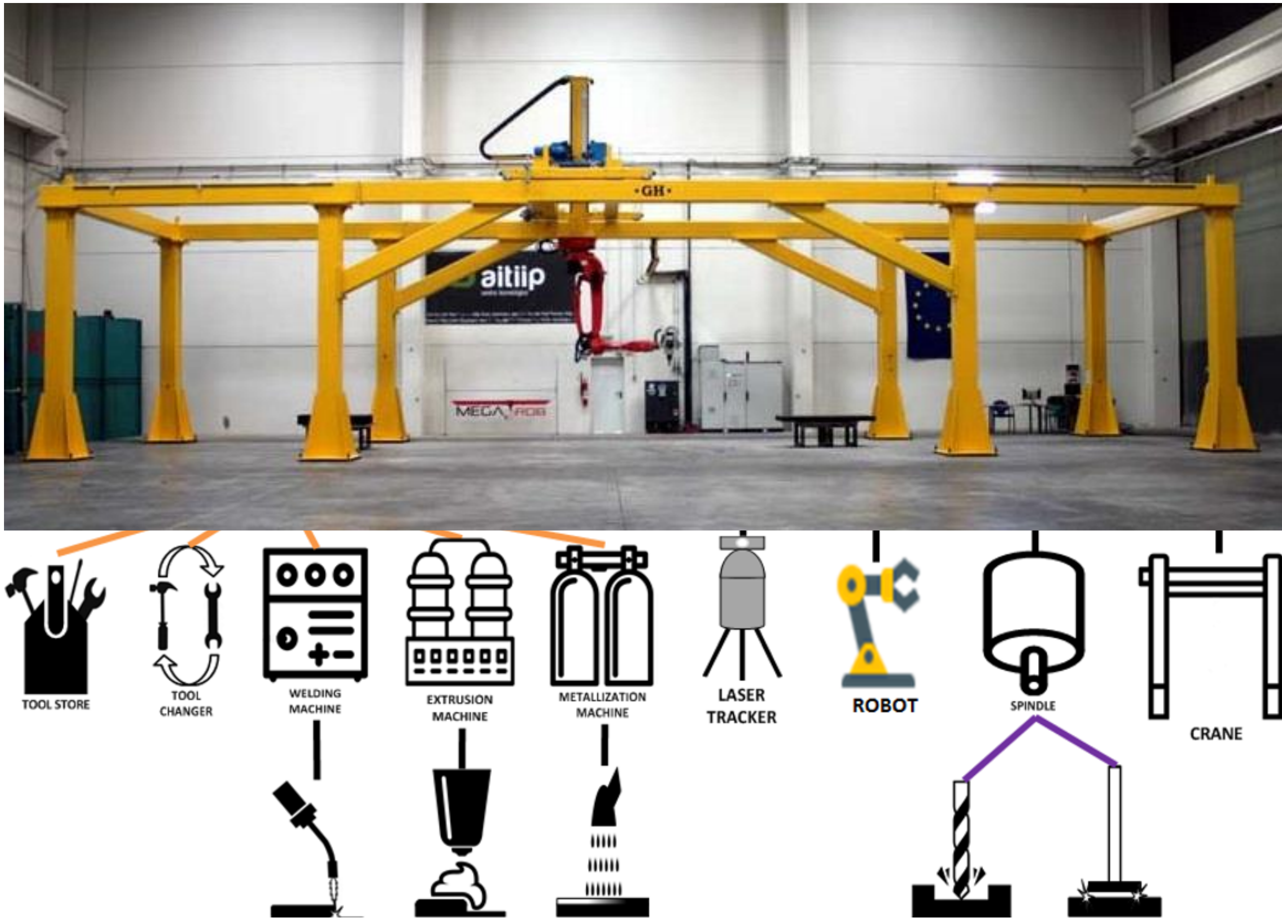


Integration in one machine



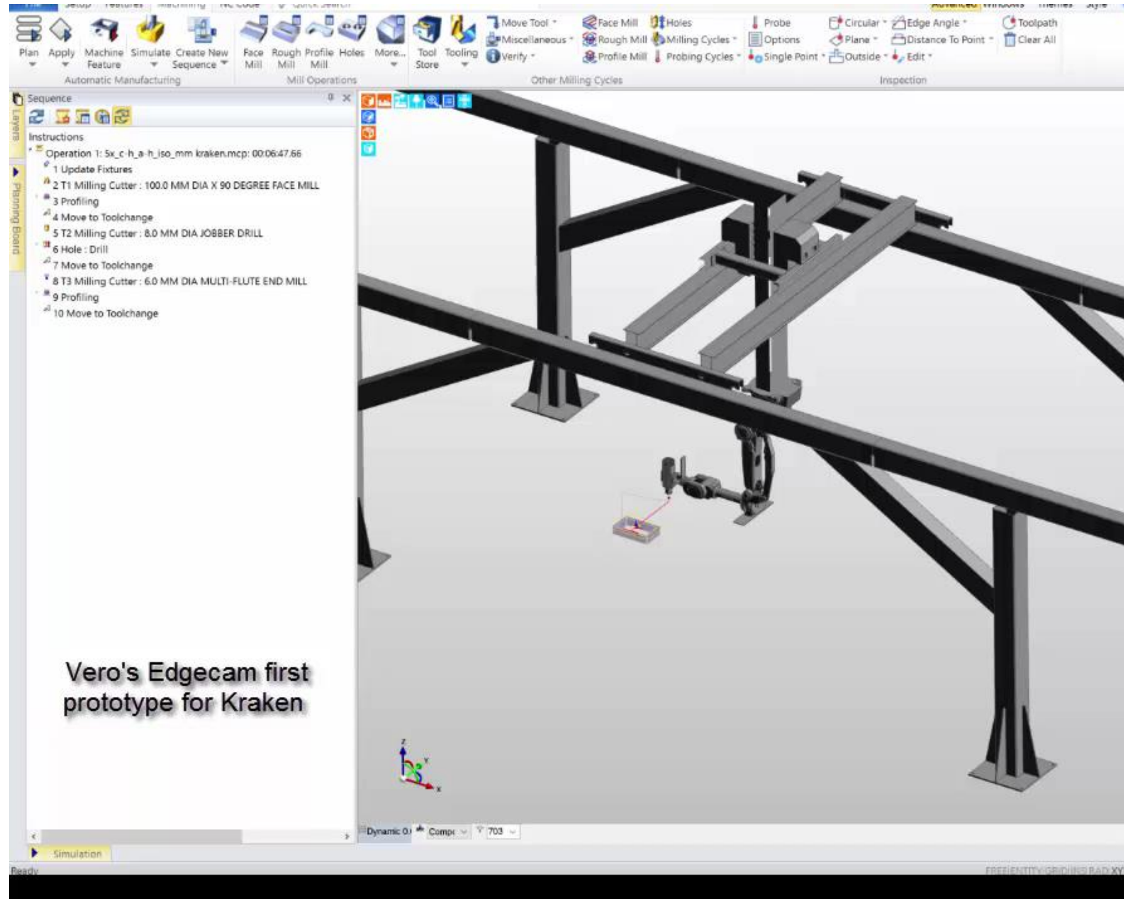
Integration of all processes in one only machine. Hybrid manufacturing machine for large components production

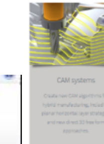


Software Development (Off line)

Multipurpose CAM software for Kraken

- AM metal CAM
- AM resin CAM
- Subtractive CAM
- Hybrid manufacturing path planning
- Postprocessing
- Virtual movement simulation

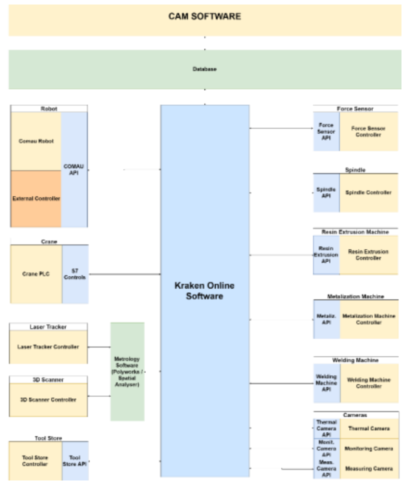


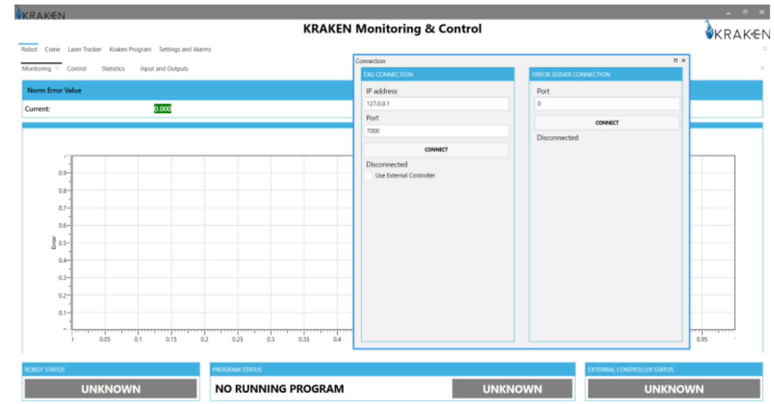


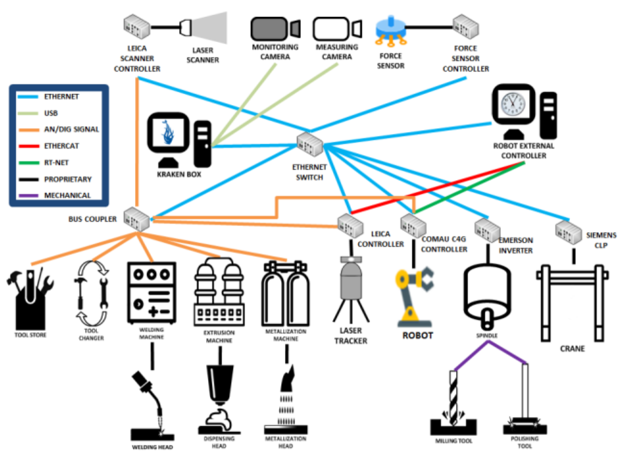
Software Development (Monitoring and Interface)

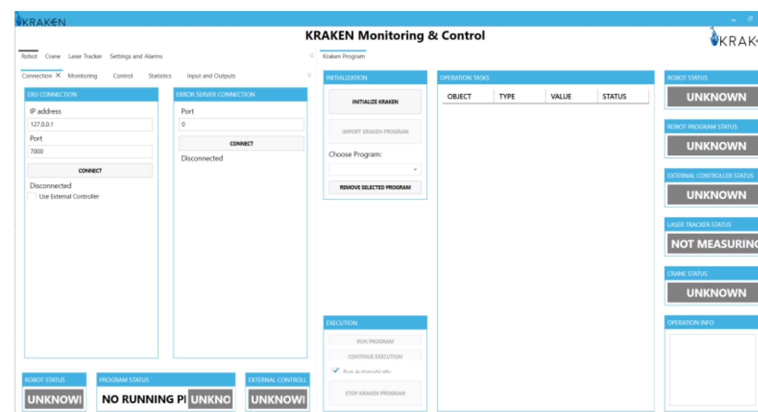
High level software

- Control of the individual elements in manual mode
- Control the full system in automatic.
- Error and parameters monitoring and reporting
- Interface for the operator









Software Development (Off line)

Demonstration Cases

Crosscutting

- Dissemination activities. Next KRAKEN workshop in EMO 2017
- More information in our website: http://krakenproject.eu/
- Follow us in the social networks
- Standardization. Kraken project is represented in several ISO/TCs and CEN/TCs regarding. Additive Manufacturing, AM for aerospace applications, Machine tools, robotics, metrology. Liaison Agreement to CEN/TC 438 “Additive Manufacturing”
- Exploitation strategy

International Conference on Additive Manufacturing

Speaker: José Antonio Dieste

(AITIIP Technological Centre)

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