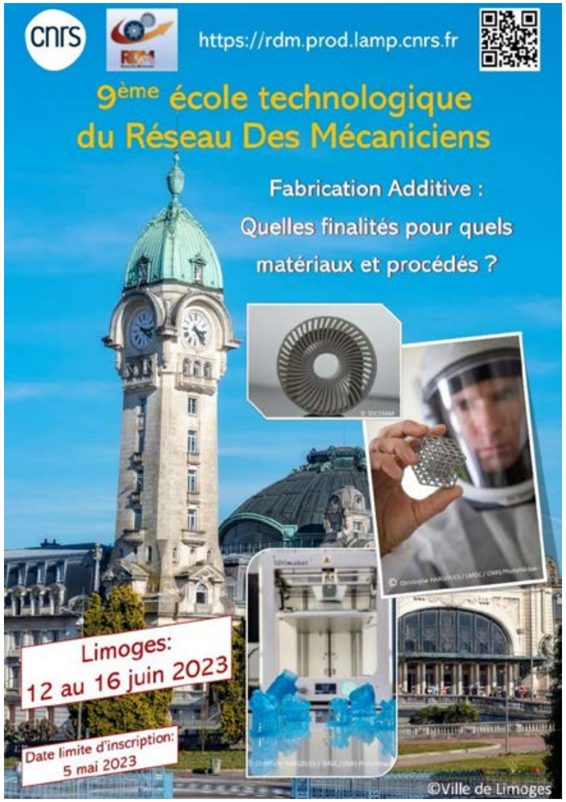


CENTRALE NANTES

LS2N LABORATOIRE DES SCIENCES DU NUMÉRIQUE DE NANTES

FRANCE ADDITIVE FILIÈRE IMPRESSION 3D

ACADÉMIE DES TECHNOLOGIES POUR UN PROGRÈS RAISONNÉ CHOISI PARTAGÉ

Une vision systémique de la fabrication additive métallique : développements, challenges et tendances pour le futur

Alain BERNARD

Professor Emeritus at Ecole Centrale de Nantes
Researcher at LS2N UMR CNRS 6004
Vice-President of France Additive
Fellow of the Academy of Technologies of France

Outline of the presentation

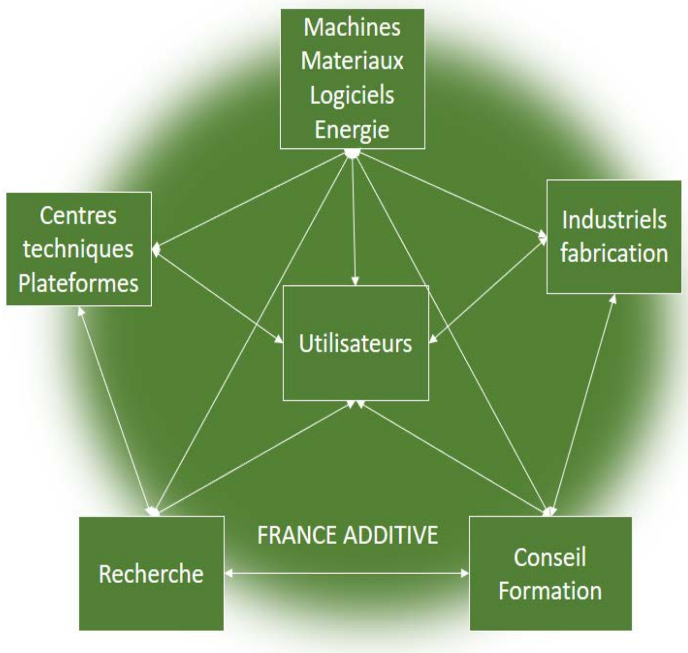
- France Additive
- Additive manufacturing: A systemic approach
- Main strengths of Additive Manufacturing
- Main future goals for Additive Manufacturing
- Conclusions

Outline of the presentation

- France Additive
- Additive manufacturing: A systemic approach
- Main strengths of Additive Manufacturing
- Main future goals for Additive Manufacturing
- Conclusions

About France Additive

- Non profit association dedicated to AM, funded in 1992
- 160+ members. Multisectors, open, neutral
- Federate research and technical centers, education, industrials, services providers and final users
- 360° scope in an open communauty mode:
  - applications
  - technologies
  - materials
  - skills
  - R&D
  - digital
  - education
  - finance
  - supply chain
  - economic growth



Source: France Additive, 2021

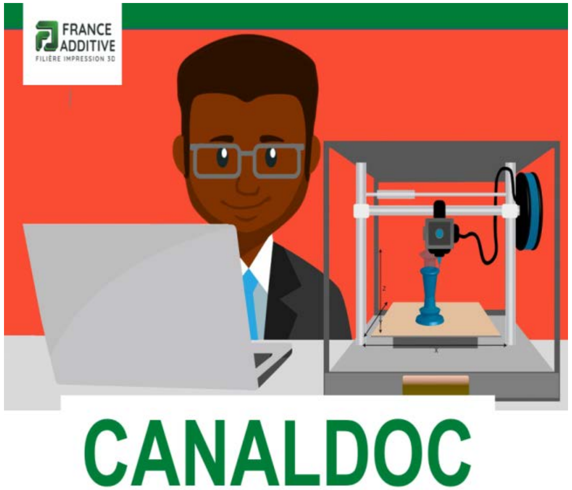
160+ members

Source: France Additive, 2021

Working groups in open community

Initiated by the members and animated by them, working groups on various topics are being proposed:

- Maintenance, repairing and repairability of parts
- Luxury – precisions and precious materials – Artisan of the future
- Automobile and new mobilities
- Large parts – DED and WAAM
- Training
- Health / Medical
- Safety at work
- SME executive club
- Program managers executive club
- Canal Doc (for PhDs and post-docs)
- …



Source: France Additive, 2021

Recent creation of a new Branch Strategic Contract

SOLUTIONS INDUSTRIE DU FUTUR

GOALS

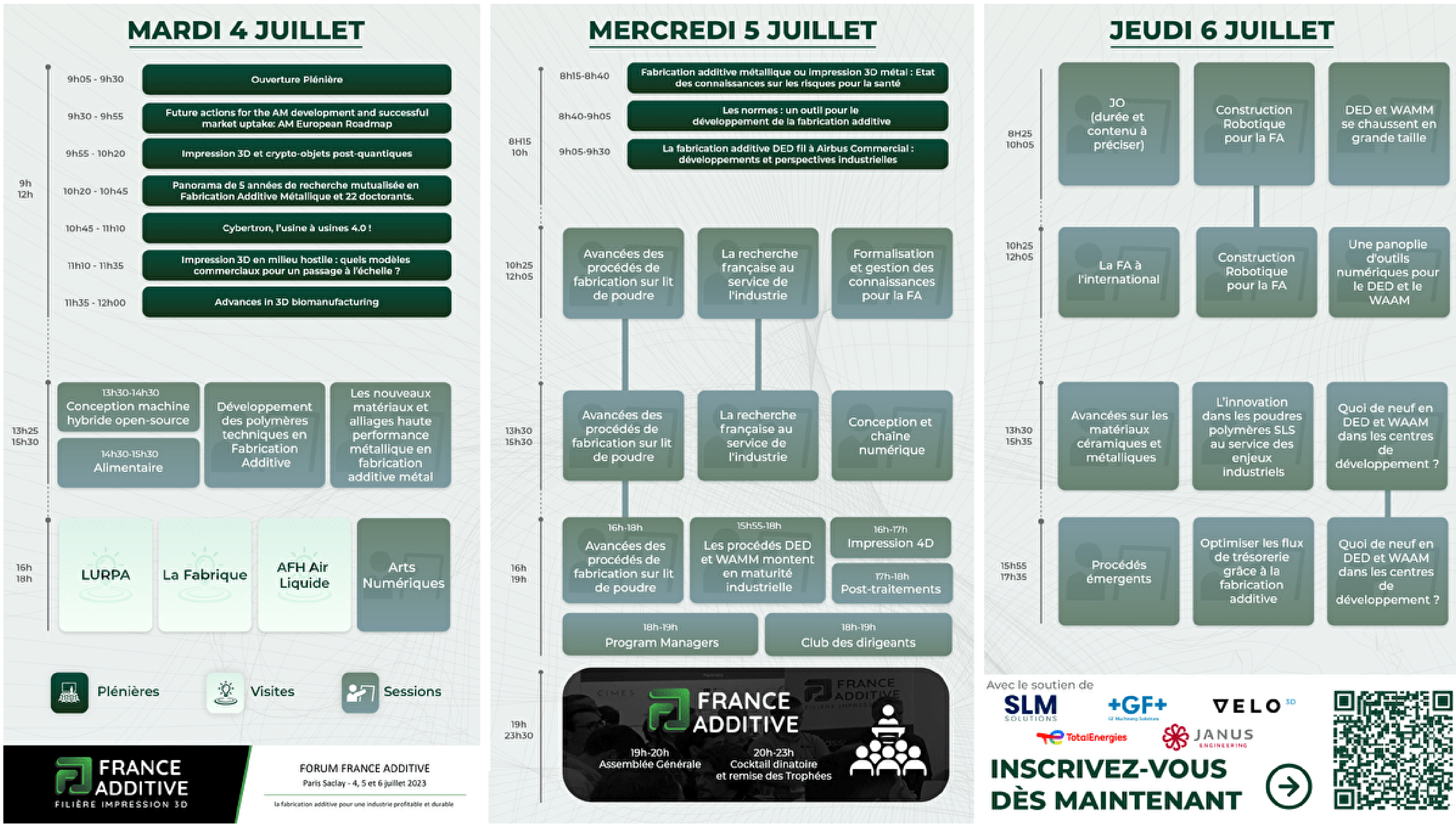
- Accelerate the development of AM in France
- Improve the competitiveness of French AM activities
- Improve the cooperation between all the actors of the ecosystem within complete value chains
- Boost the technical investments in the field of AM

Source: France Additive

Forum France Additive 2023

Source: France Additive

Forum France Additive 2023

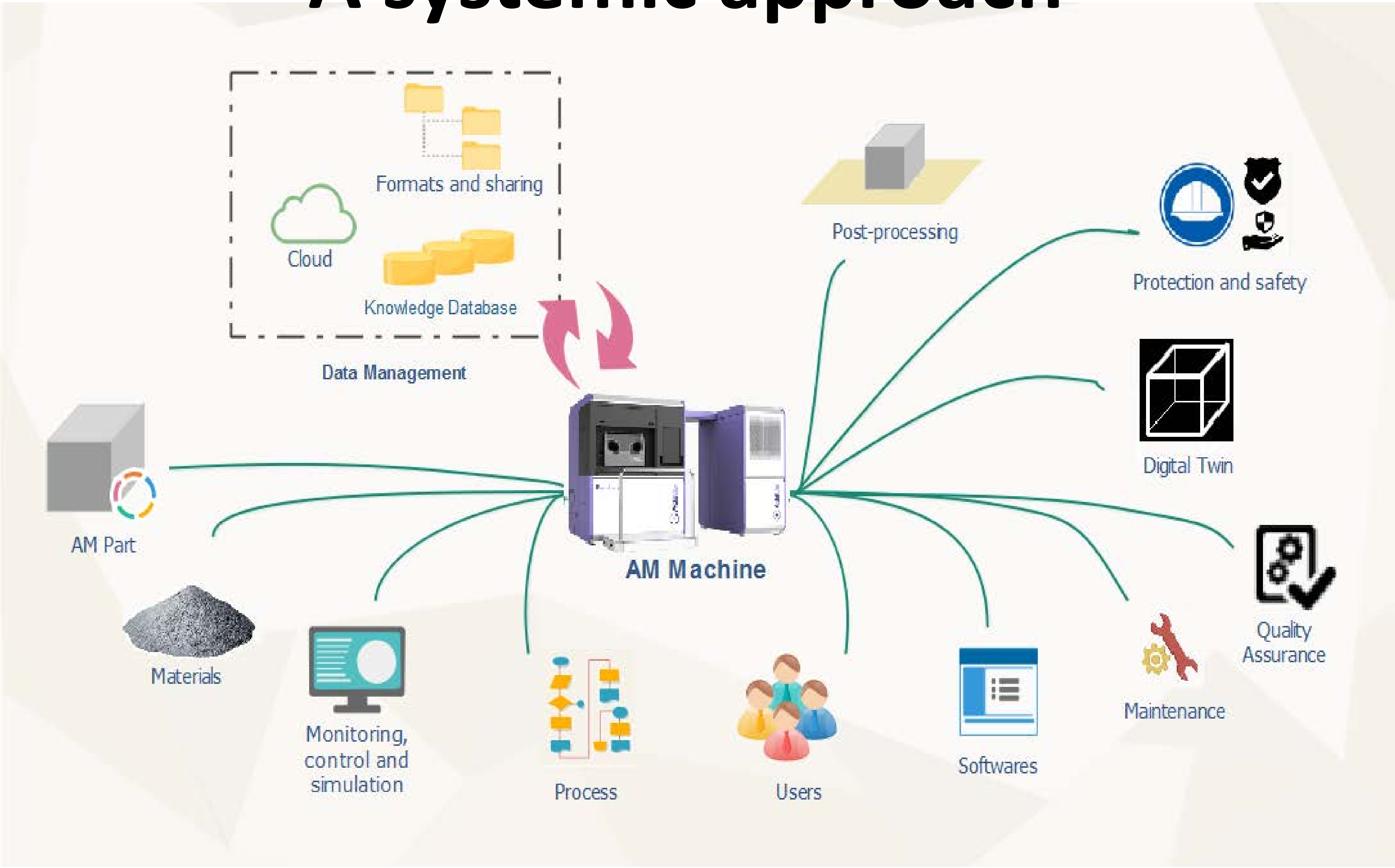


Source: France Additive

Outline of the presentation

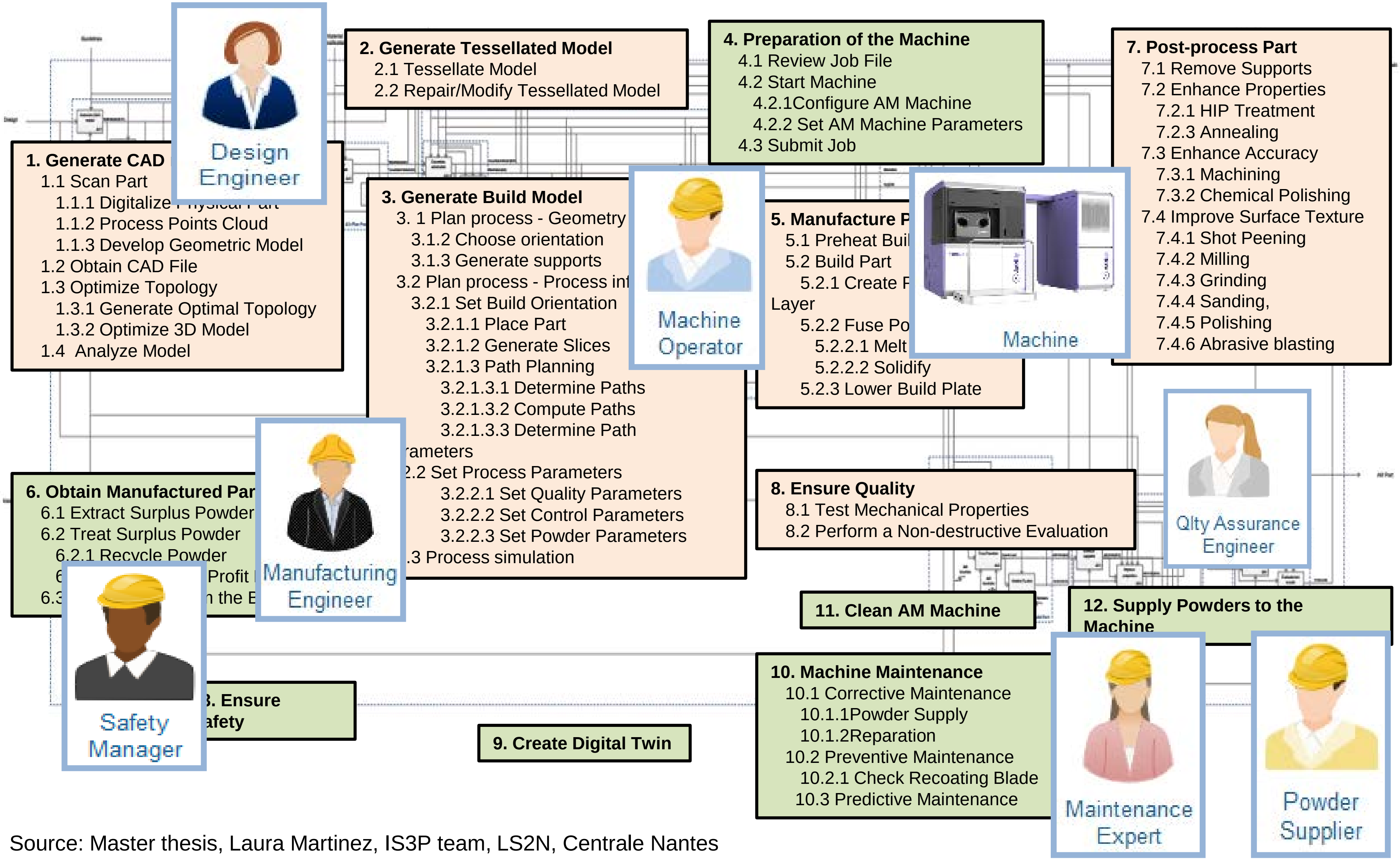
- France Additive
- Additive manufacturing: A systemic approach
- Main strengths of Additive Manufacturing
- Main future goals for Additive Manufacturing
- Conclusions

A systemic approach



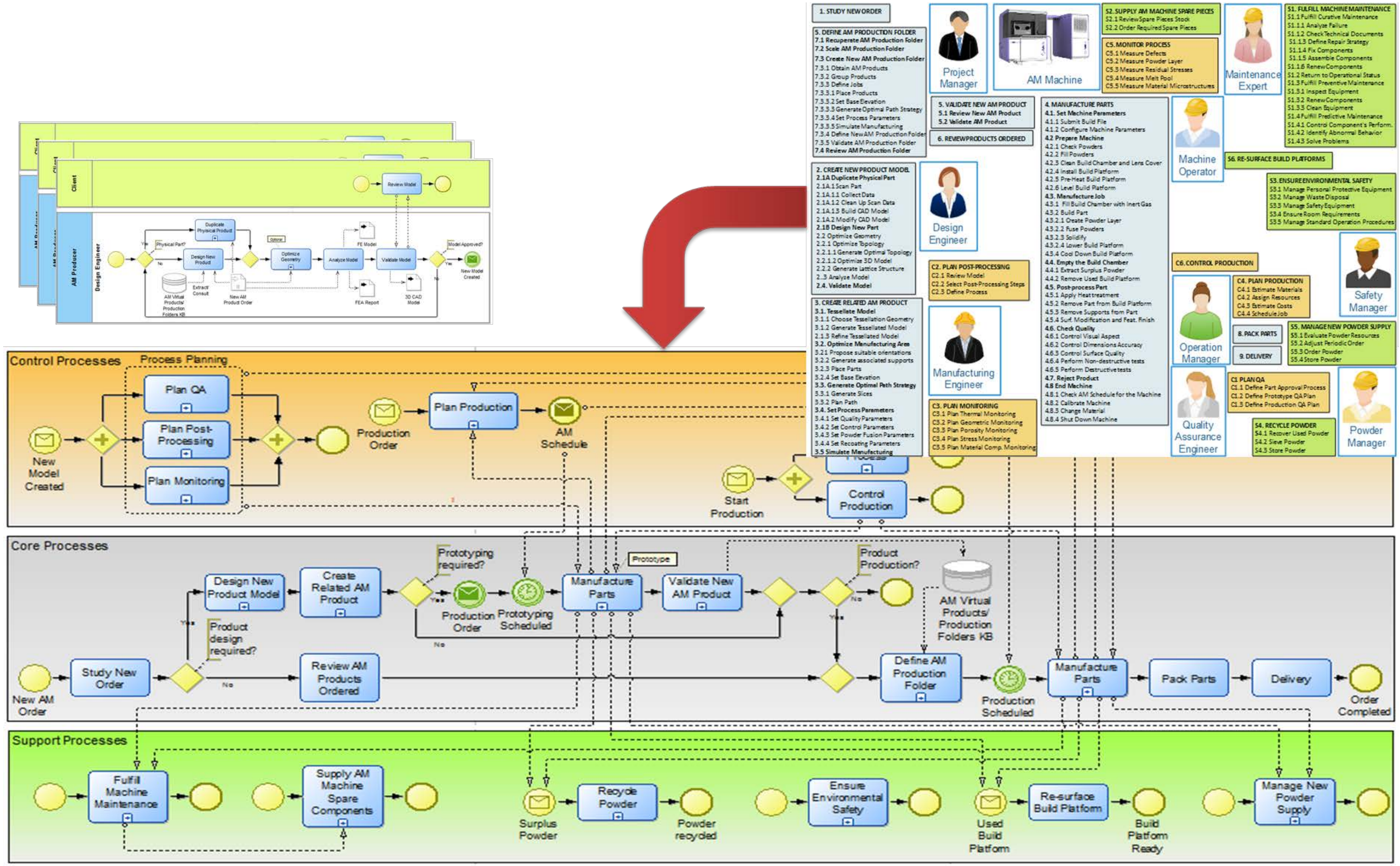
Source: Master thesis, Laura Martinez, IS3P team, LS2N, Centrale Nantes

A systemic approach



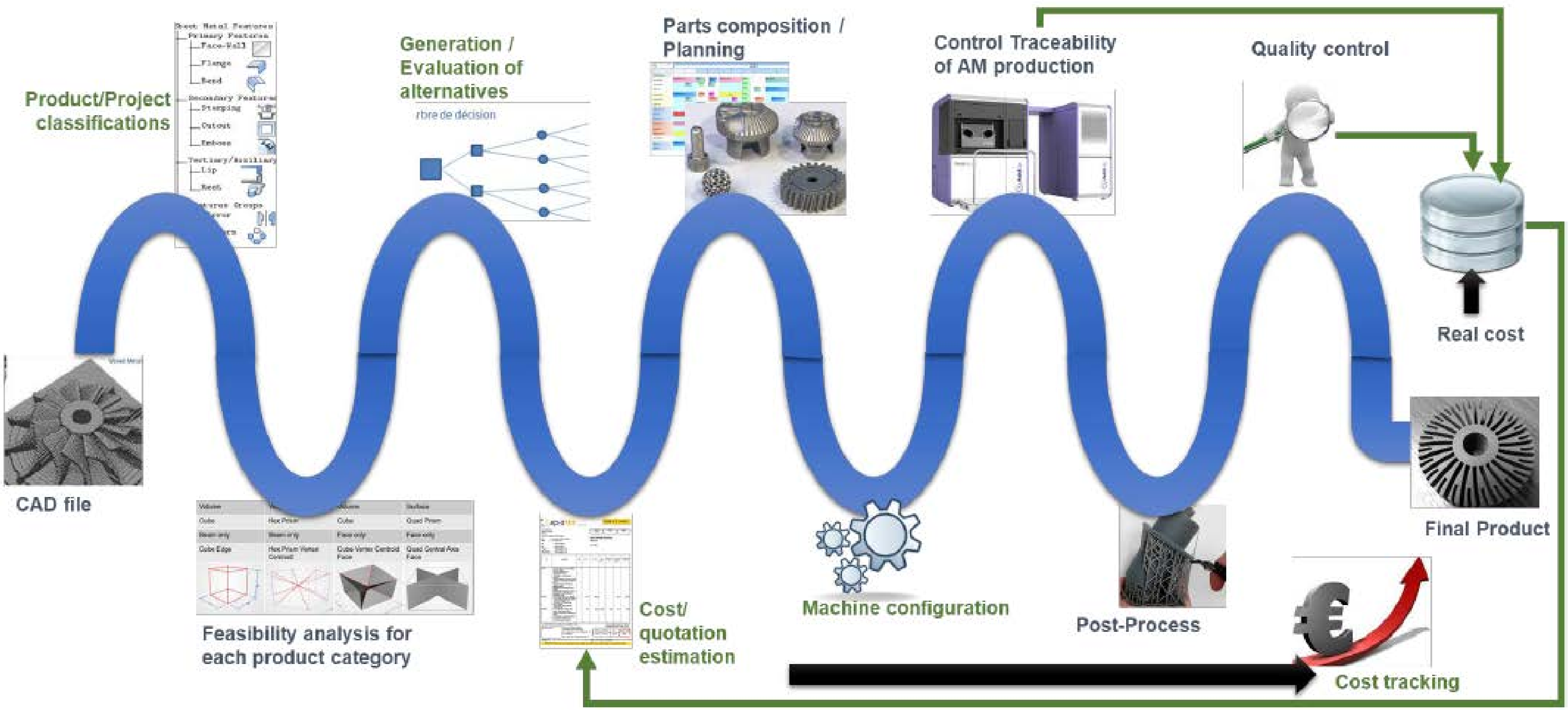
Source: Master thesis, Laura Martinez, IS3P team, LS2N, Centrale Nantes

A systemic approach



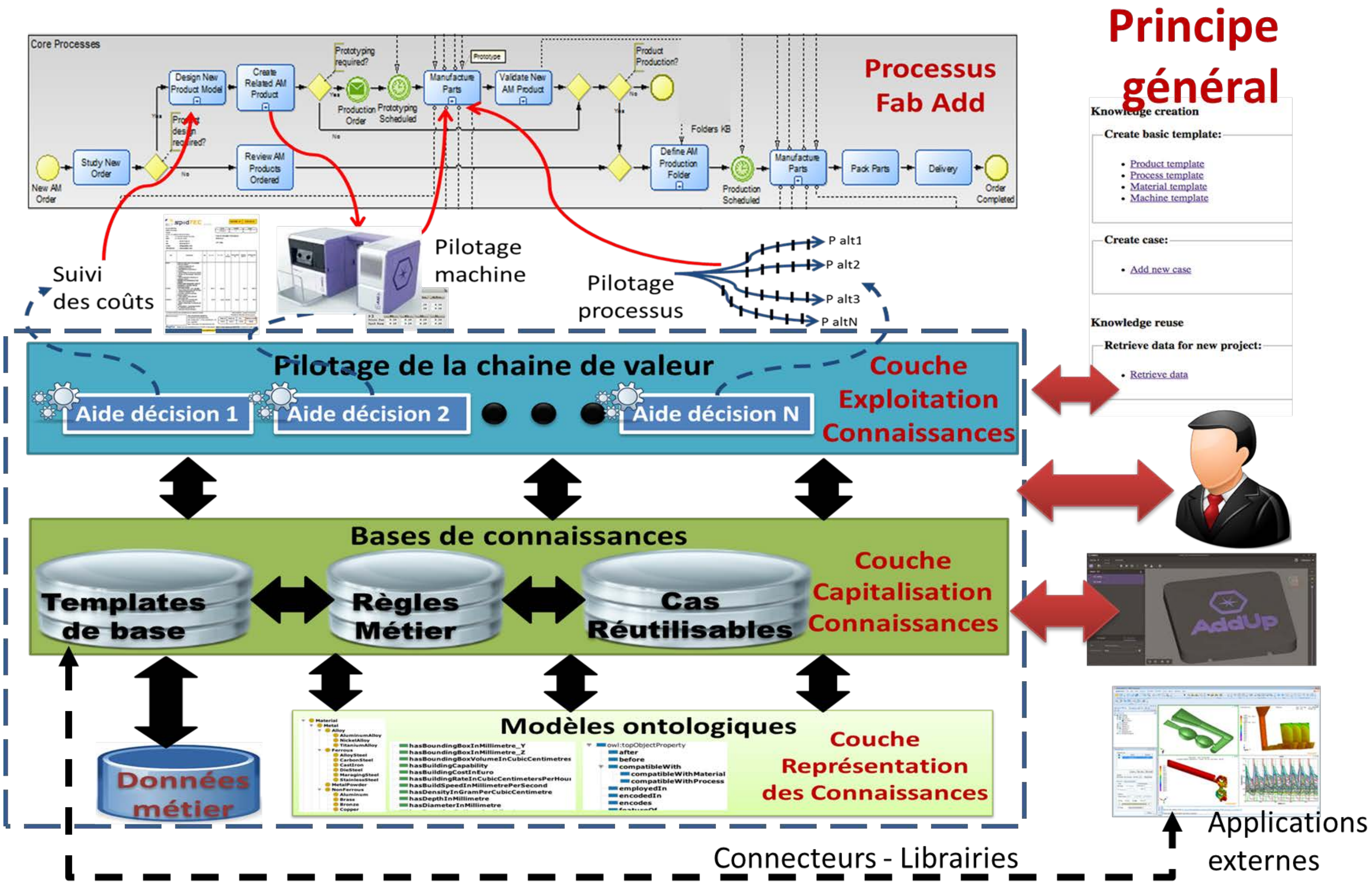
Source: PhD work in SOFIA project, Qussay JARRAR, IS3P team, LS2N, Centrale Nantes

A complete value chain



Source: PhD work in SOFIA project, Qussay JARRAR, IS3P team, LS2N, Centrale Nantes

A framework for value chain control



Source: PhD work in SOFIA project, Qussay JARRAR, IS3P team, LS2N, Centrale Nantes

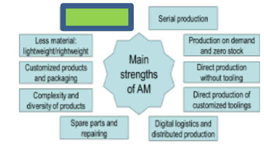
Outline of the presentation

- France Additive
- Additive manufacturing: A systemic approach
- Main strengths of Additive Manufacturing
- Main future goals for Additive Manufacturing
- Conclusions

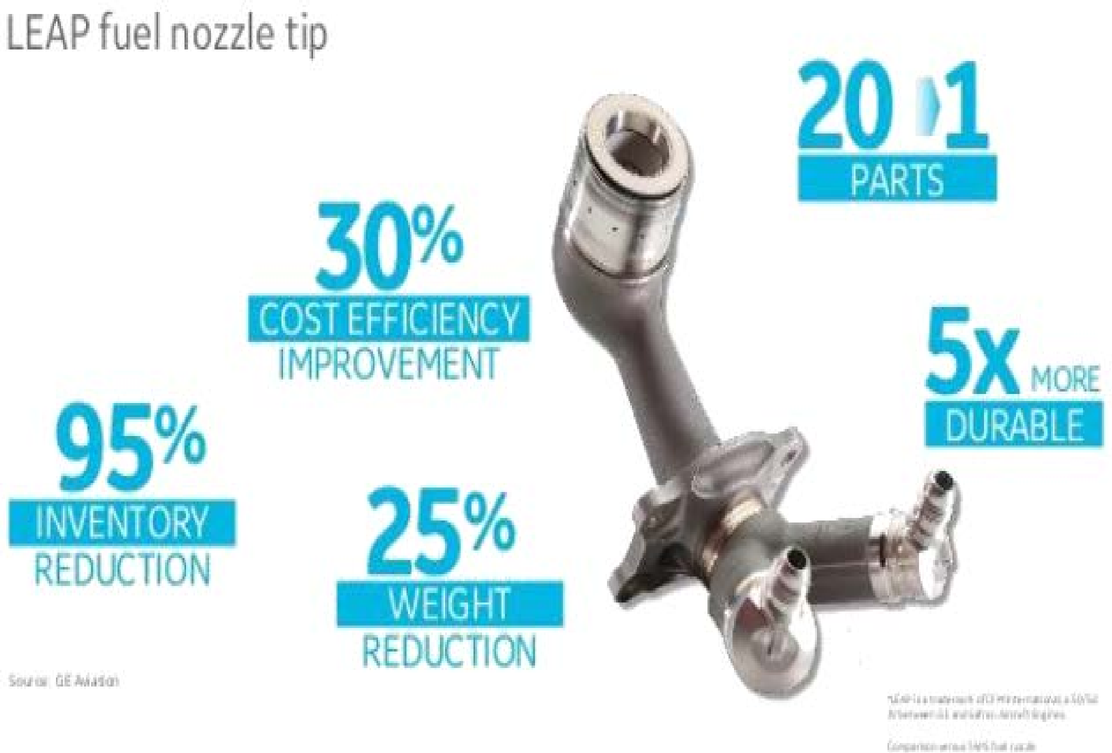
Main strengths of Additive Manufacturing

Main strengths of AM

- Functional optimization
- Serial production
- Less material: lightweight/rightweight
- Production on demand and zero stock
- Customized products and packaging
- Direct production without tooling
- Complexity and diversity of products
- Direct production of customized toolings
- Spare parts and repairing
- Digital logistics and distributed production



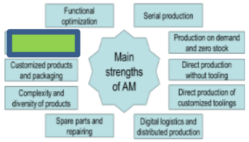
Functional optimization



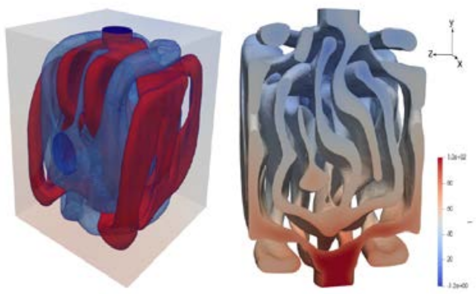
Source: Farinia Group

Source: General Electric/Ian Gibson, 25th European Forum on Additive Manufacturing, 8-10 June 2021

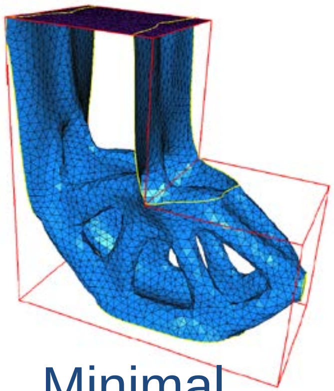
Less material: Lightweight/rightweight



Heat exchanger design



Source: Grégoire Allaire, Laboratoire CMAP, Ecole Polytechnique



Minimal weight and compliance

Hydraulic blocs

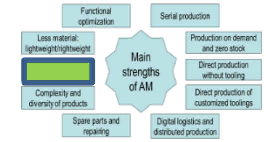
Source: Yicha Zhang, UTBM

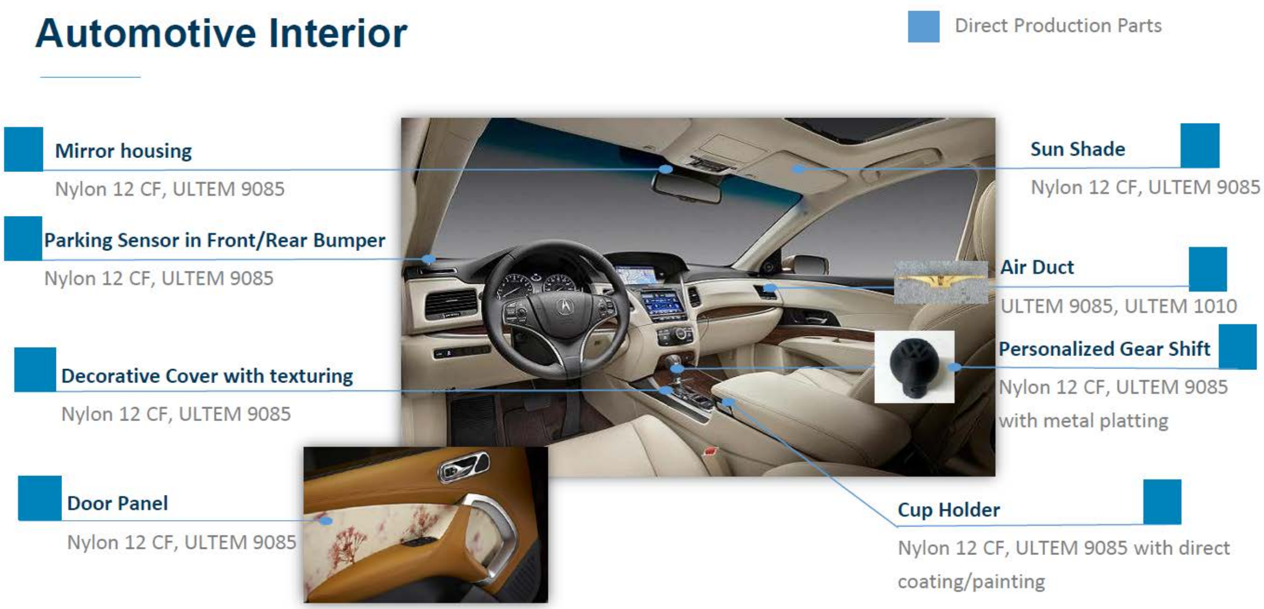
Heat exchangers

Source: Olaf Diegel, Aukland, New Zealand

Source: Olaf Diegel, Aukland, New Zealand

Customized products/packaging

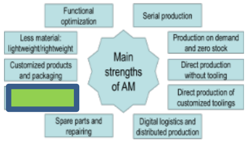


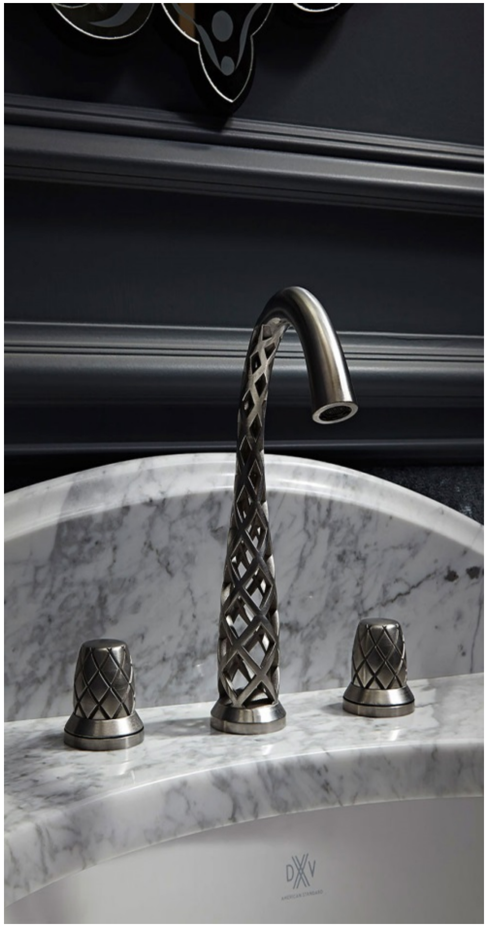


Source : Stratasys

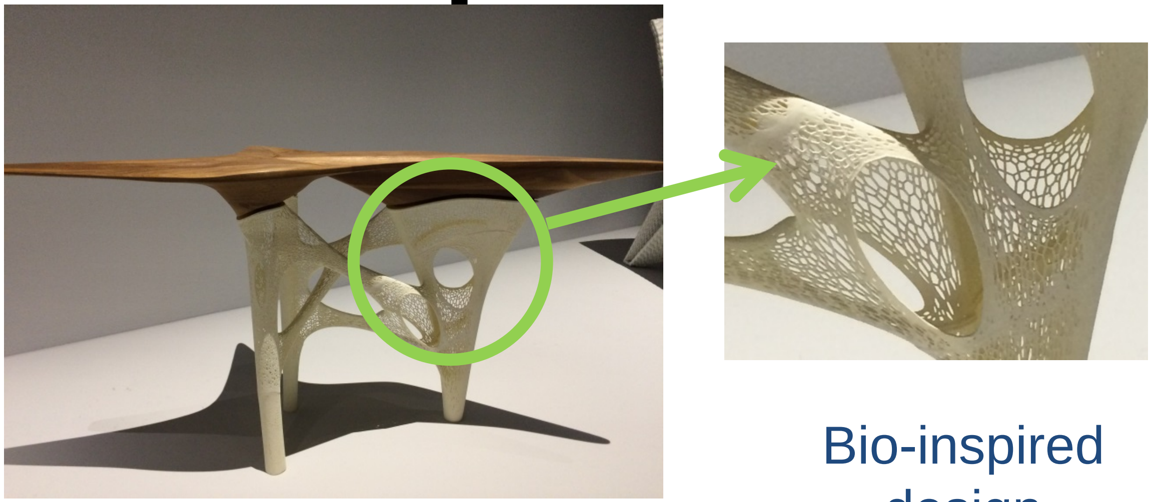
Personnalized Packaging
Pack&Strat (patented by CIRTES)
Source: CIRTES

Complexity and diversity of products/bio-inspired





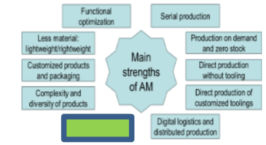
Deluxe Tapware by American Standard



Source : « imprimer le Monde » exhibition, Centre Pompidou, mars 2017

Bio-inspired design

Parts manufactured by Volum-e company



Spare parts and repairing

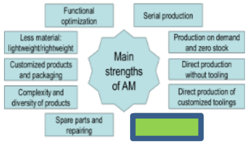
- **Additive Manufacturing (AM)** allows the production of spare parts:
  - **Short lead time** (even **on demand**) → **reduced inventory** level & **decreased** supplier **dependency**
  - Close to the point of use → **reduced environmental** footprint

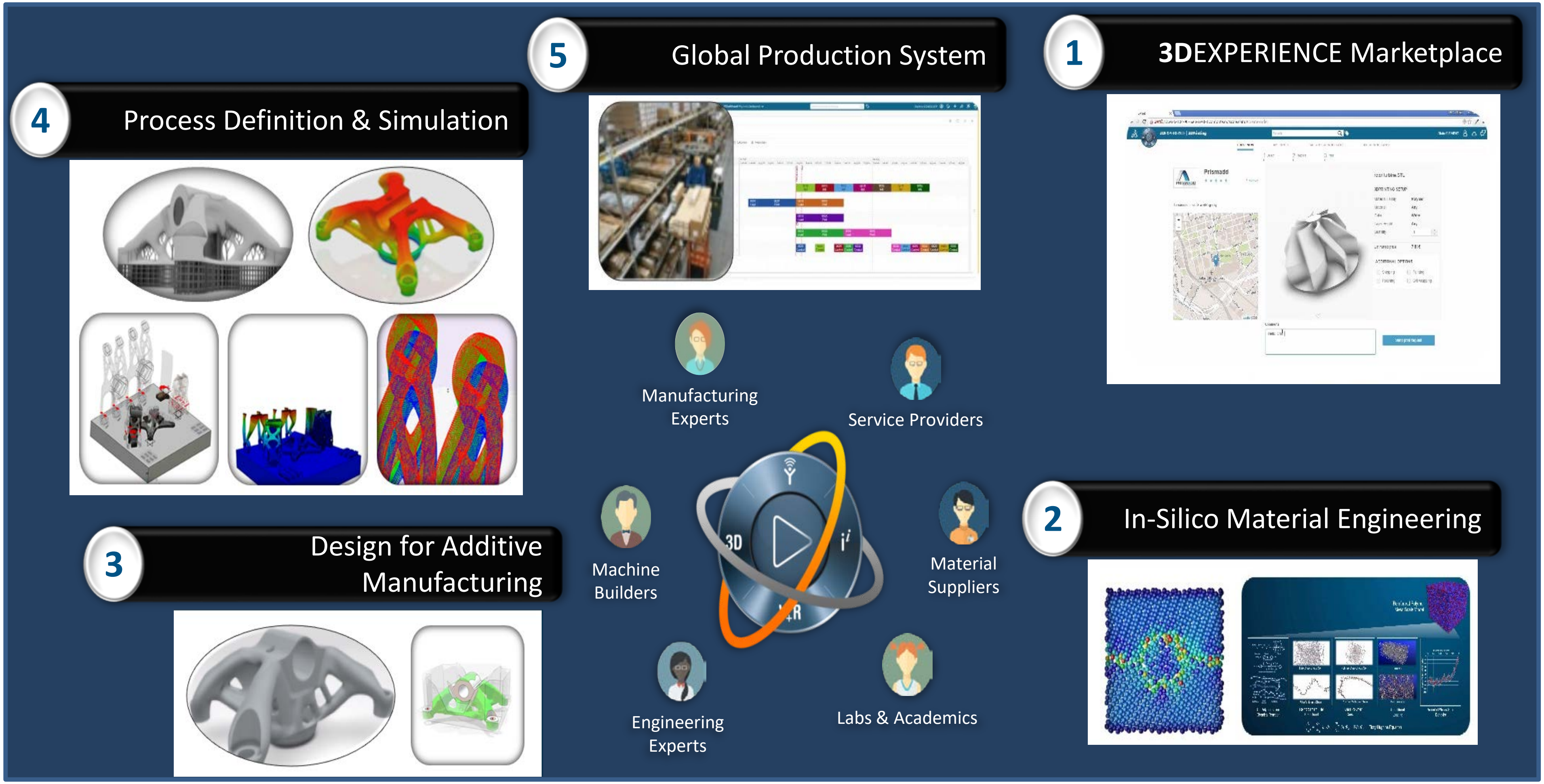
- **Increasing interest** in AM for spare parts production, but:
  - **High Production costs** → can be offset by the decreased inventory costs
  - **Uncertain reliability** → main limitation of AM

➔ To what extent does the uncertainty in the reliability impact the choice between AM and Conventional Manufacturing (CM) based on economic considerations?

Source : Additive or Conventional Manufacturing for Spare Parts: Effect of Failure Rate Uncertainty on the Sourcing Option Decision
Mirco Peron, Rob Basten, Nils Knofius, Francesco Lolli, Fabio Sgarbossa, BEST PAPER AWARD, MIM 2022 IFAC conference

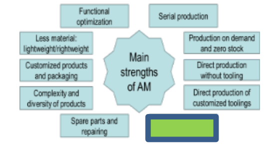
Digital logistics/ distributed production

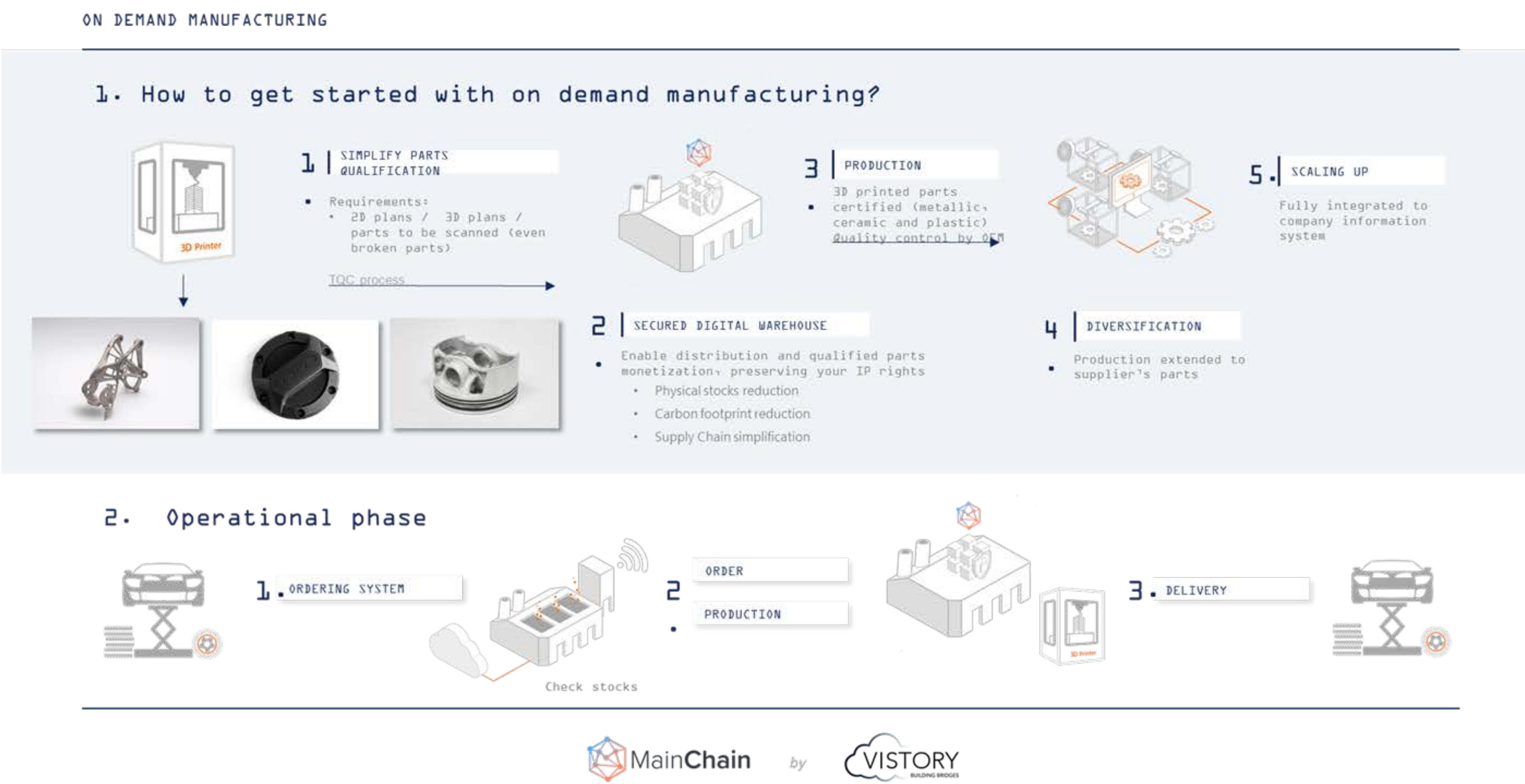




Source: Daniel Pyzak, Dassault Systèmes Additive Manufacturing solutions 3DExperience

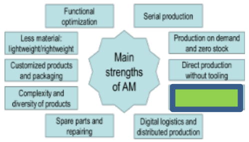
Digital logistics/ distributed production



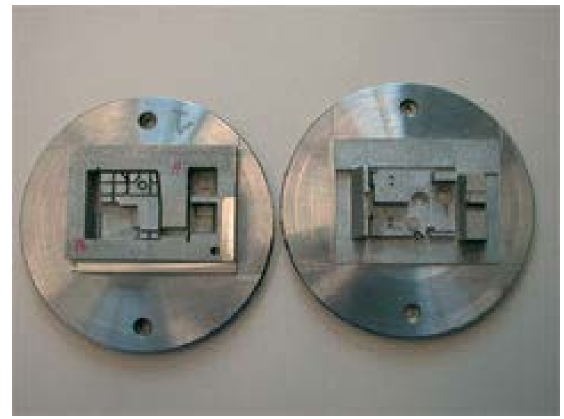


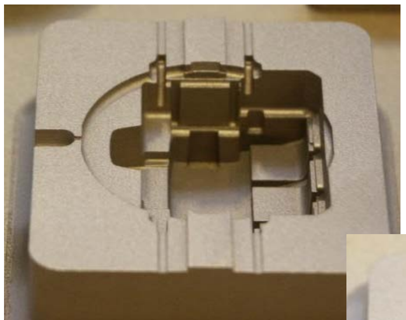
Source: Alexandre Pedemonte, Vistory Company

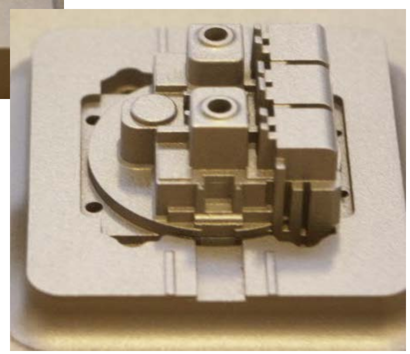
Direct production of customized toolings



Inserts in molds
Source: Realizer

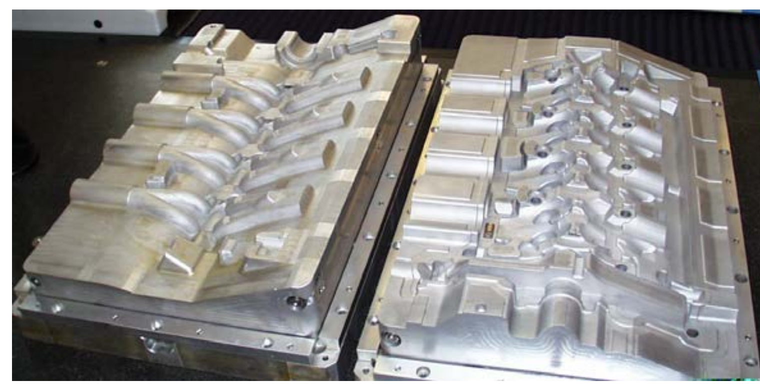






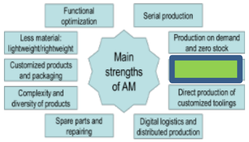
Inserts in molds
Source: PEP

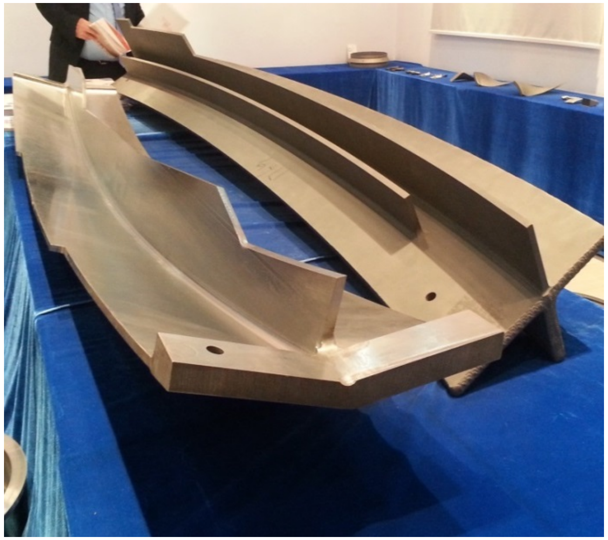
Blowing tools
Source: CIRTES



Injection molding toolings - PS Application PMP
R&D contract PSA / CIRTES
(Aluminium)

Direct production without tooling



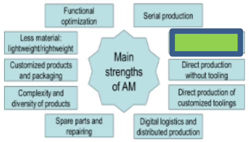


Source: Georges Fadel, AEFA 2015

Credit photo for these four pictures: Alain Bernard

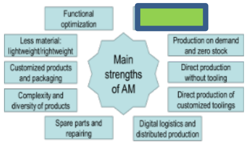
Source: Volum-e, Courtesy: Airbus defense and space

Production on demand and zero stock

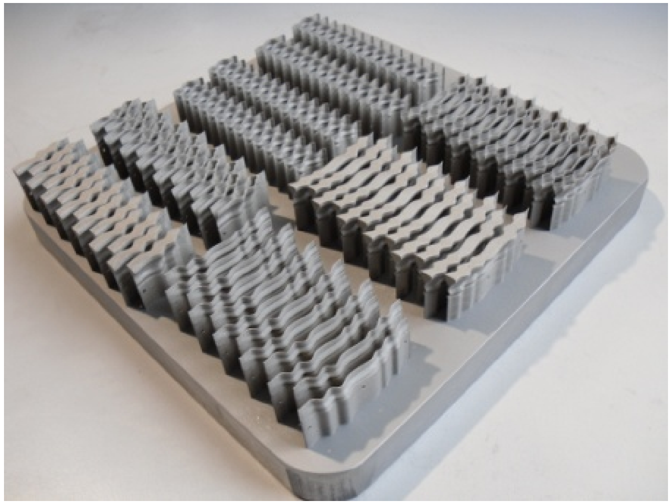


Source:http://www.camboxisis.fr/shop/fr/content/16-3dprinting

Serial production



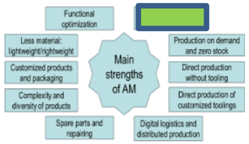
Source: Georges Fadel, AEFA 2015

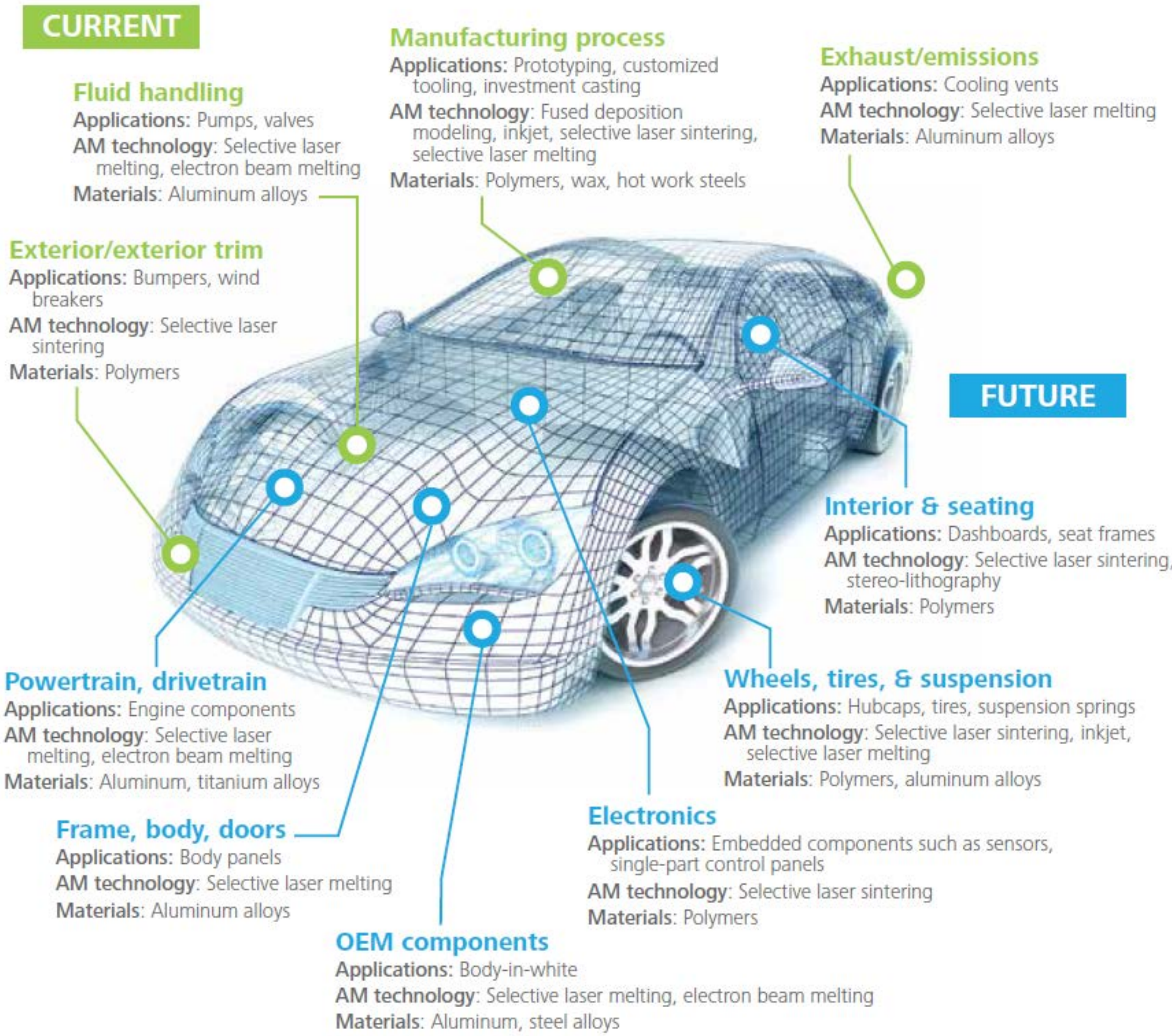


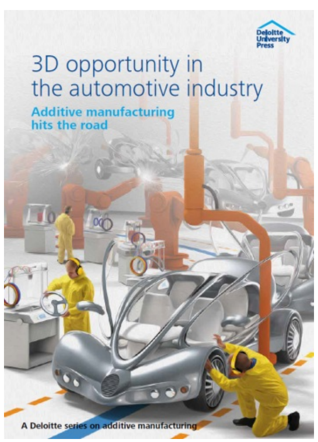
Source: Phenix Systems

Batch production of a propeler
Source: Naval Group

Serial production





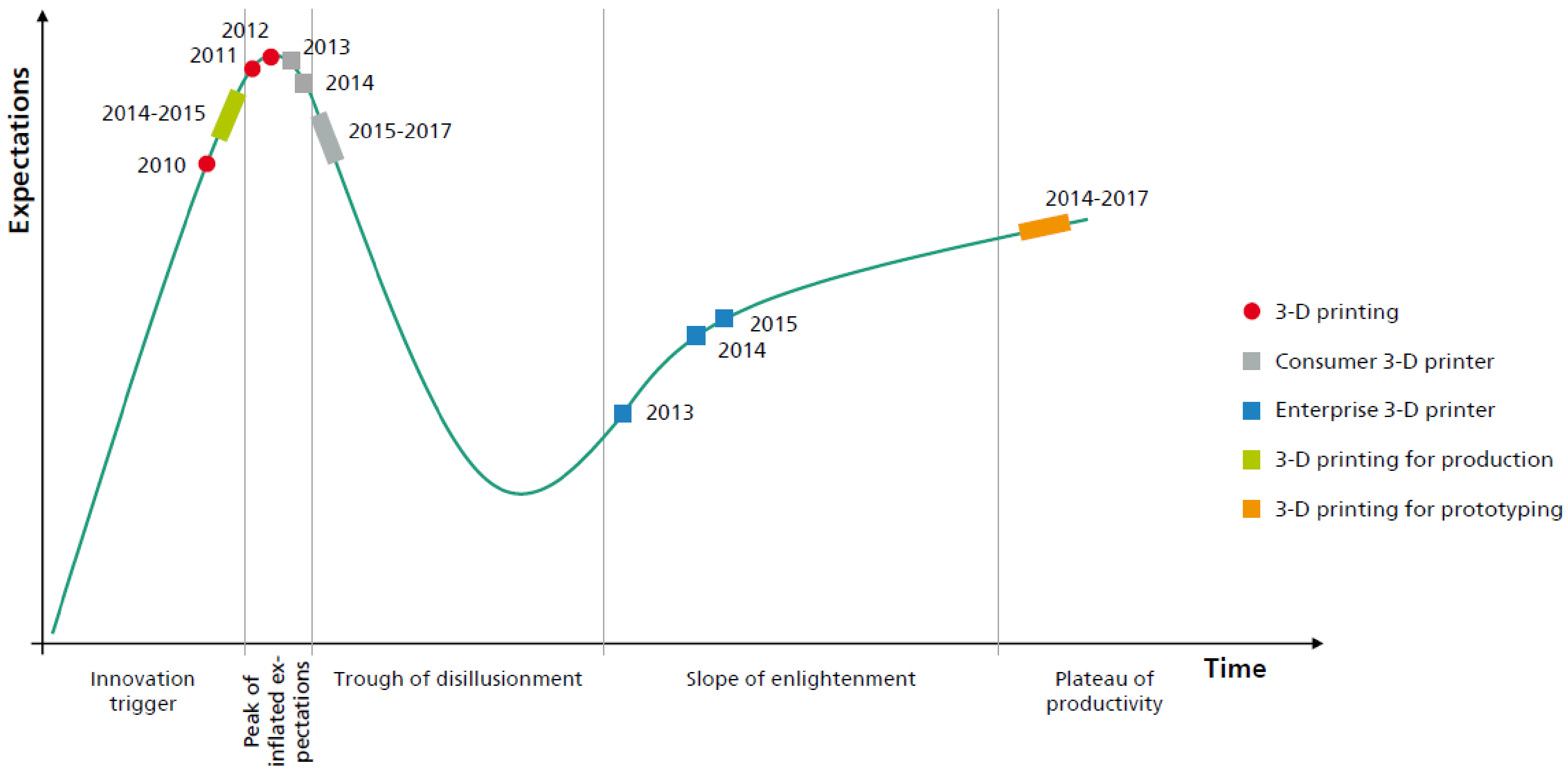


Source: A Delotte series on additive manufacturing

Outline of the presentation

- France Additive
- Additive manufacturing: A systemic approach
- Main strengths of Additive Manufacturing
- Main future goals for Additive Manufacturing
- Conclusions

Gartner's Hype cycles for emerging technologies (2010-2017)



Source: Jochen LOOCK, Head of Academy, Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT Hamburg

The TRL in Aeronautic Industry

TRL 6-7: Titanium (Airbus)

- First civil application are going to serial production

TRL 9: FDM Ultem (Airbus)

- Fully certified flying cabin parts in serial production and after sales + tools & customized solutions

TRL 9: Polyamide 22FR (Boeing)

- Used since years for venting & air ducts on many programs

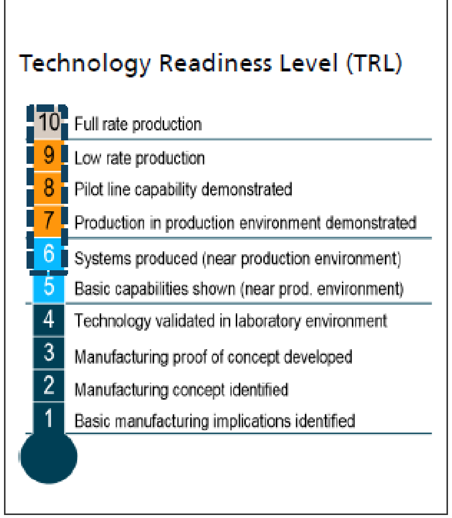
TRL 9-10: Cobalt-Chrome (GE)

- Fuel Nozzle flight tested and in mass production

TRL 9: Inconel (MTU)

- Ramp-up of serial production for the engines

First players on the verge of (part specific) TRL 10



Source: Jochen LOOCK, Head of Academy, Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT Hamburg

The TRL in Medical and Dental sectors

TRL 10: Titanium

- More than 100.000 Hip Implants were manufactured using SLM & EBM technology.

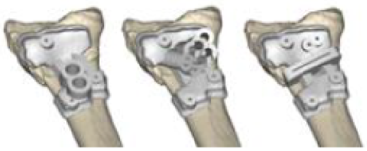
TRL 10: Cobalt-Chrome

- >12.000 Crowns and Copings for dental usage are produced daily

TRL 10: Polymers

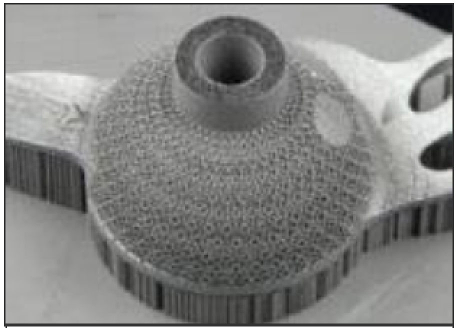
- Around 50% of all hearing aids are today manufactured

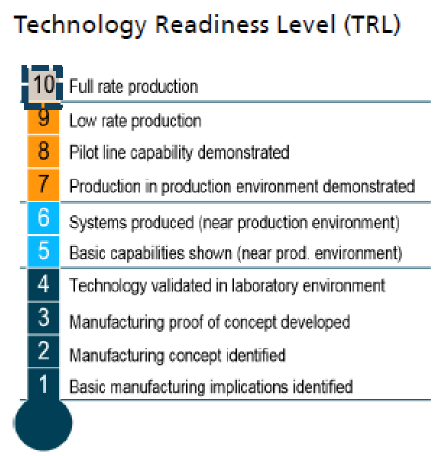
- Mass production of Surgical Guides in SLS



TRL 9: (Stainless) Steel

- Customized medical instruments for surgeons





> Most advanced industry; driver → customization

Source: Jochen LOOCK, Head of Academy, Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT Hamburg

The TRL in Automotive Industry

TRL 6-8: Metals

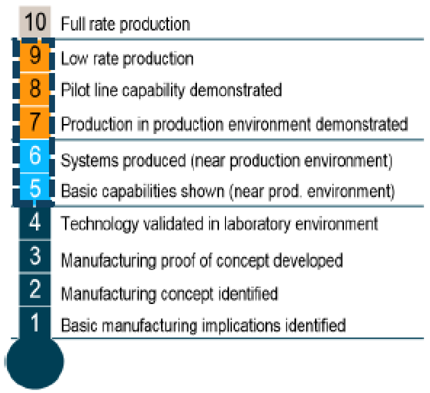
- Focus on product development (prototyping), Tooling and exotic small series
- Broader usage in motor sports & Formula 1 (e.g. gearboxes & exhaust systems)
- First application ins after-sales (esp. classic cars)
- Lightweight parts are examined for electrical cars
- First applications on luxury cars at Bugatti, Audi and BMW are on the verge to serial production

TRL 6-9: Polymers

- Rolls Royce Phantom is using 10.000 parts in small serial production (e.g. hazard flush, sockets and other polymer clips)
- Daimler is starting 2016 to use SLS for small series and repair of Trucks
- PA12 & ABS: Prototyping for interior parts (dashboard, doors,...)
- BMW is customizing e.g. interior for Mini

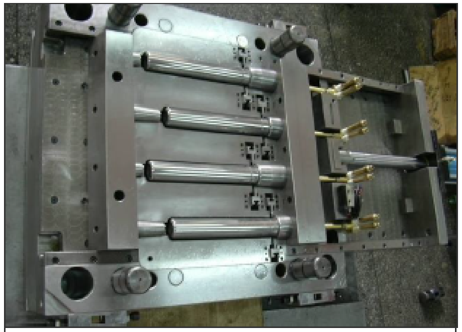
First automotive application are going to serial production

Technology Readiness Level (TRL)



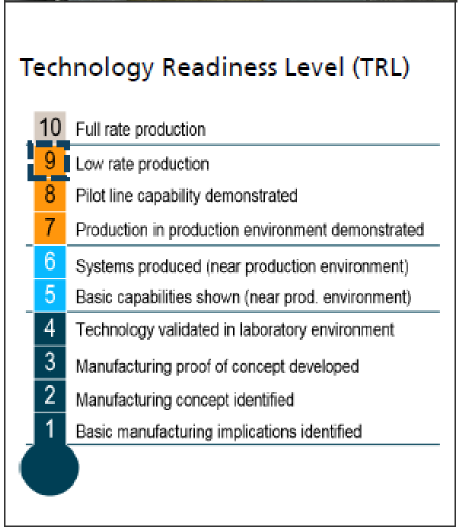
Source: Jochen LOOCK, Head of Academy, Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT Hamburg

The TRL in Tooling and Machine building



TRL 9: Steel

- Tool manufacturer Mapal is using steel (1.2709) for serial production of hybrid drills with optimized cooling channels
- LBM enables smaller drills (8-12mm diameter) compared to traditonal manufacturing
- Additive steel tools for deep drawing, stamping and moulding applications



TRL 9: Aluminium & Polymers

- Used for various applications in final part production

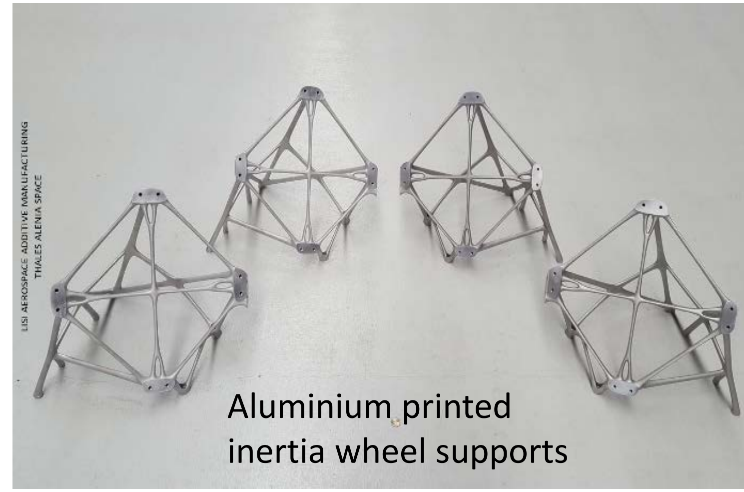
Lower qualification burdens lead to greater adoption

Source: Jochen LOOCK, Head of Academy, Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT Hamburg

Industrial maturity

Thalès created a new plant in Morocco

Safran is creating a new competence center in Bordeaux



Aluminium printed inertia wheel supports

LISI Aerospace Additive Manufacturing

Lamborguini produced more than 20 000 parts in 2020

Tank cap (EPX 82)

Fixing element for air duct (EPX 82)

Ventilation grid (EPX 82)

Anti-condensation for canopy

Dassault Aviation

Recent progresses

Magnetic materials

À Nancy,
Le 4 juin 2021

COMMUNIQUÉ DE PRESSE

Un premier procédé direct d'impression d'aimants en 3D


Télécharger le visuel

Les équipes de l'Institut Jean Lamour – IJL (CNRS / Université de Lorraine) viennent de relever un véritable défi technologique : intégrer des propriétés magnétiques à des matériaux imprimés en 3D, sans post-aimantation. Il s'agit là d'une première mondiale avec ce niveau de performance et ces travaux ouvrent la voie à l'impression 4D d'objets magnéto-actifs. Ce procédé de fabrication d'aimants avec une imprimante 3D grand public est en cours de transfert au sein d'une entreprise du Grand Est.

Une prouesse technologique

Cette innovation technologique associe différentes compétences présentes à l'IJL : celles de l'équipe de recherche technologique Matériaux et Procédés Additifs, dirigée par Samuel Kenzari, ingénieur de recherches CNRS, et celles du Centre de Compétences Magnétisme et Cryogénie dirigé par Thomas Hauet, maître de conférences à l'Université de Lorraine. Le défi qu'ont relevé les chercheurs et ingénieurs est celui de concevoir une imprimante 3D de type FDM (dépôt de filament fondu) avec son fil magnétique composite pour imprimer des pièces elles-mêmes magnétiques.

Pour fabriquer le fil, ils ont utilisé des matériaux ferromagnétiques avec des formulations propres à les rendre imprimables. Pour ce qui est du dispositif d'impression, ils sont partis d'une imprimante 3D traditionnelle, à laquelle ils ont ajouté des composants permettant la mise en forme de l'aimant pendant l'impression. Les pièces produites par cette imprimante possèdent une ou plusieurs orientation(s) magnétique(s) permanente(s) sans nécessiter l'application d'un champ magnétique a posteriori pour les aimanter.

Une commercialisation prévue pour l'automne 2021

Une déclaration d'invention[1] a été déposée en 2019 et un contrat de licence de savoir-faire a été passé avec l'entreprise BB Fil basée à Heiligenberg en Alsace. La commercialisation d'une version grand public du procédé d'impression (imprimante et filament d'impression) est prévue pour l'automne 2021 : il deviendra ainsi possible d'imprimer des aimants personnalisables chez soi.

Ces travaux ouvrent la voie à l'impression 4D d'objets magnéto-actifs, qui pourront être déformés, activés ou commandés par un champ magnétique.

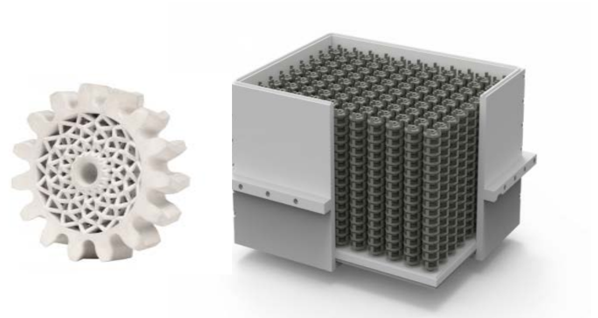
Ces travaux ont bénéficié du soutien du CNRS, de l'Université de Lorraine, de Lorraine Université d'Excellence, de la Région Grand Est et d'ICEEL.

[1] "Matériaux et procédé direct d'impression 3D d'objets magnétiques mono- ou multi-orientés" référencée à la SATT SAYENS avec le n°DISATTGE-275.

CONTACT PRESSE
Capucine François
Chargée des relations presse
06 71 00 07 80

Source : Université de Lorraine

Desktop Metal becomes first to qualify 4140 steel for binder jet 3D printing technology



Fully dense sinterable 6061 aluminum alloy parts

Source : https://3dprintingindustry.com/news/desktop-metal-becomes-first-to-qualify-4140-steel-for-binder-jet-3d-printing-technology-191116/

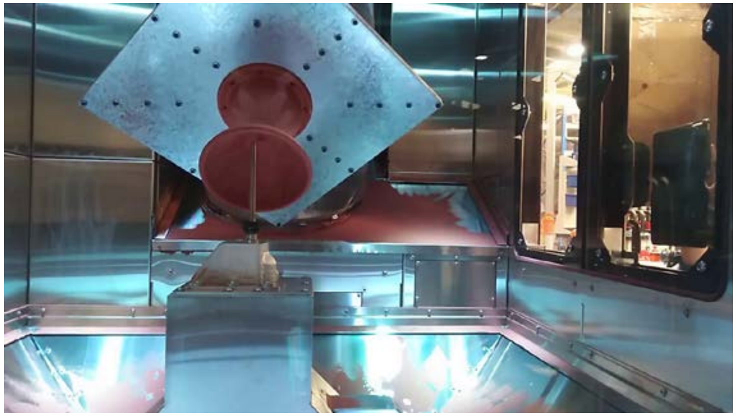
Digital Metal® first in the world to offer pure copper as printing material.

Other materials: stainless steel 316L and 17-4PH, tool steel DM D2, super alloys DM 625 (Inconel 625), DM 247 (MAR M247) and Titanium Ti6Al4V.

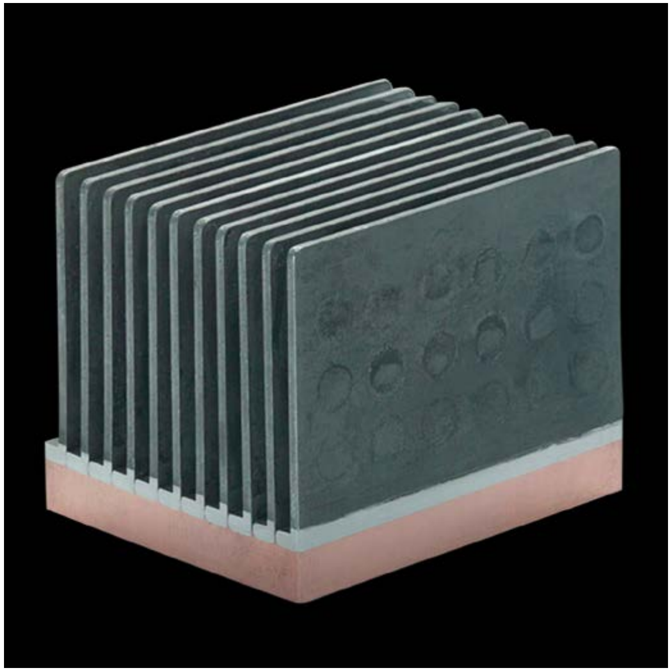
Recent progresses

WarpSPEED3D cold spray machine
Speed of building: 100 g/min

Cold spray with supersonic air flow (Aluminum and copper)



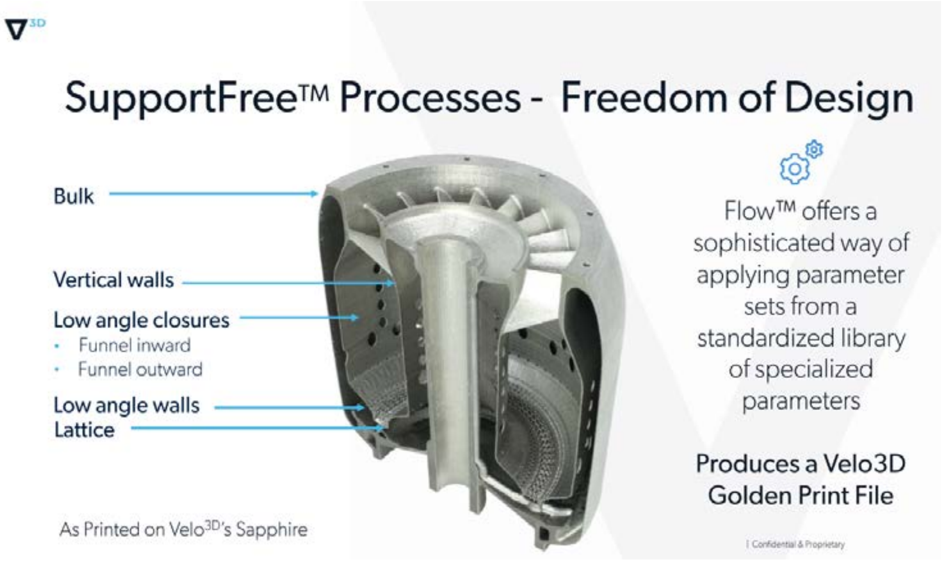
18 kg / 3 hours



Copper over aluminum

Source : https://www.spee3d.com/elementum-3d-adopts-award-winning-cold-spray-metal-3d-printing-technology/

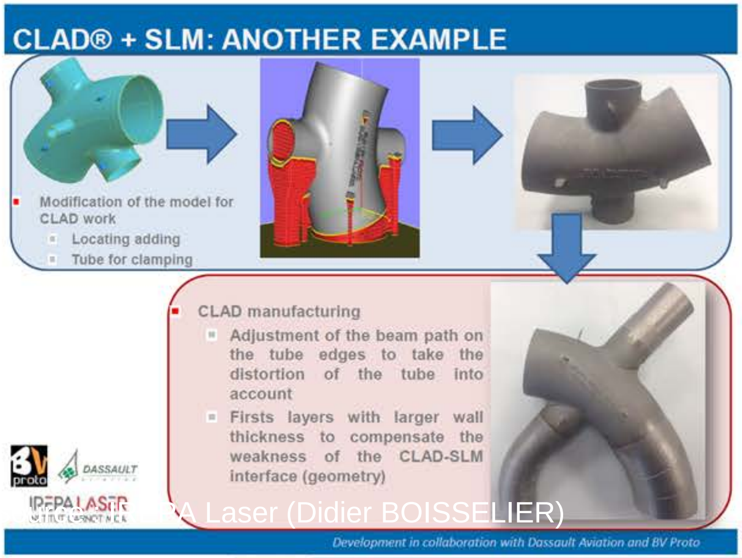
Velo3D with support free solution



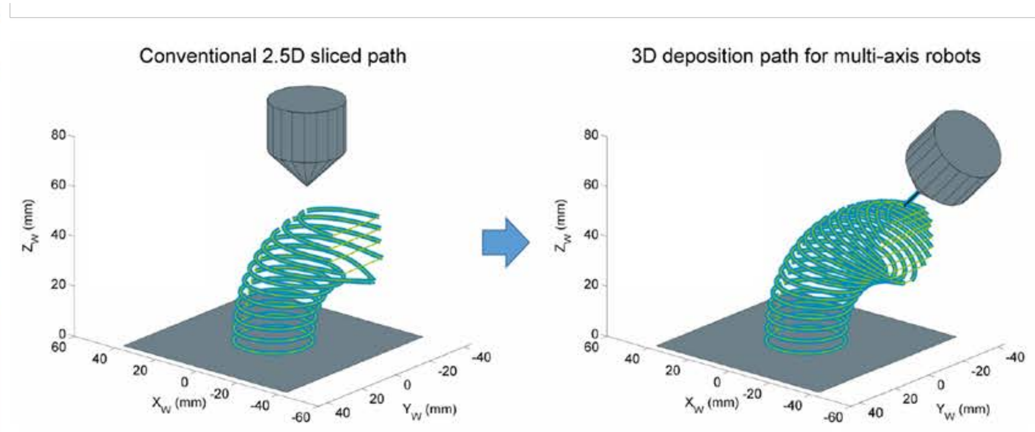
Source : Velo3D company

Recent progresses

Hybrid manufacturing – multi-material parts



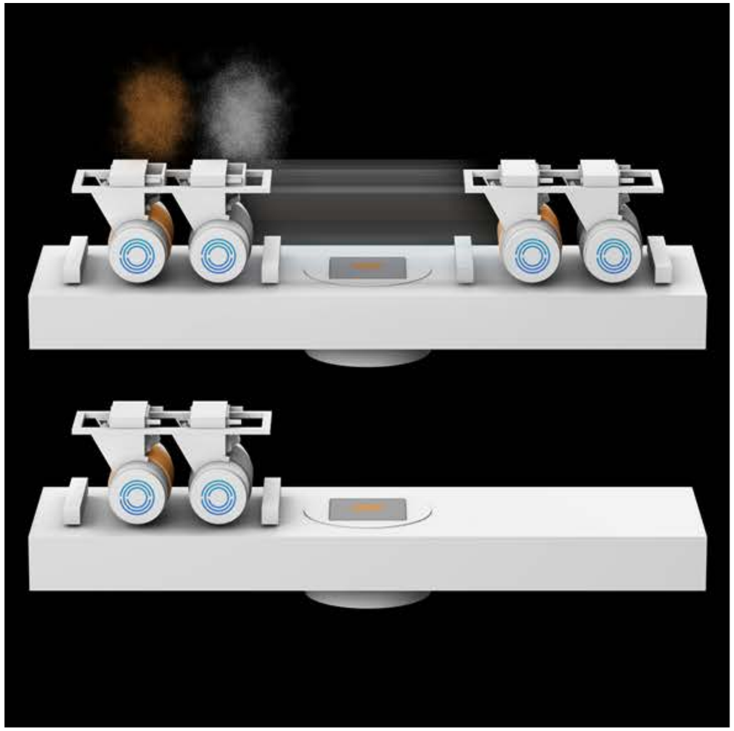
[…]PA Laser (Didier BOISSELIER)



Source : Campocasso, 2017: S. Campocasso, V. Hugel, B. Vayre. *Génération de trajectoires pour la fabrication additive par dépôt de fil robotisé multi-axes-Application à une tubulure torique*. 15ème Colloque national AIP-Primeca, 2017.

Crédit photo : Alain BERNARD

Recent progresses



Desktop Metal – Aerosint with be-material deposition

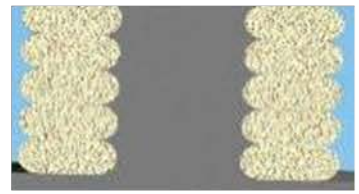
Example of heat exchanger

Source : Desktop Metal - https://aerosint.com/

New materials for realistic models

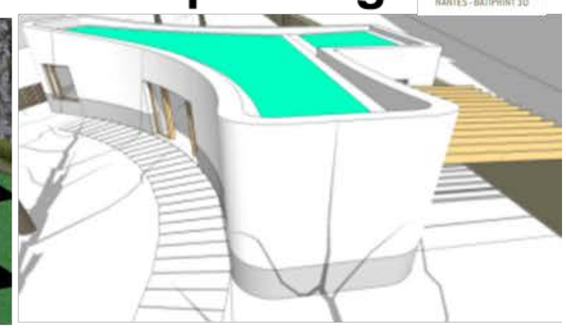
Source : Olaf Diegel, Aukland, New Zealand

Direct production in construction



BATIPRINT3D™

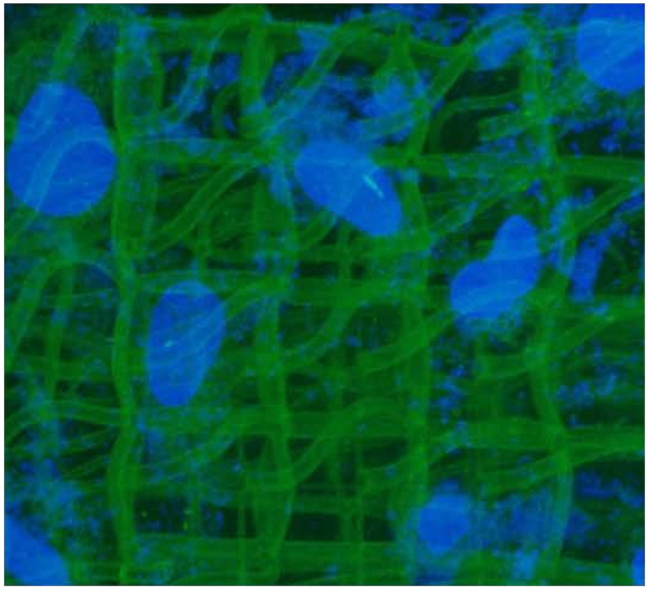
A new 3D printing method for building
Combination of foam and concrete 3D printing.



Projet Yhnova

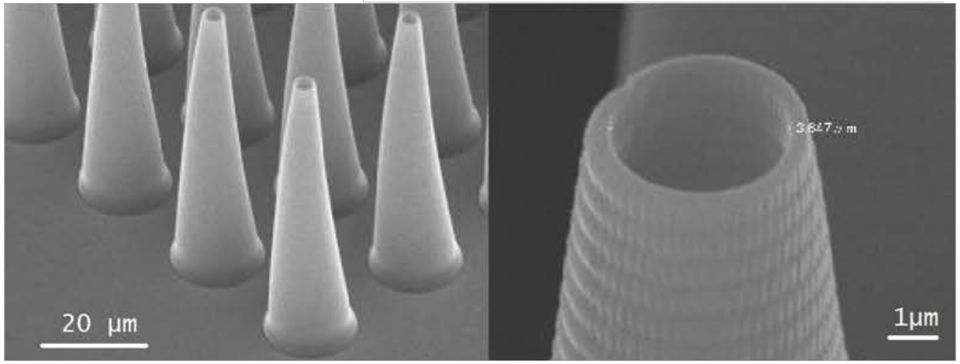
Source: Benoit FURET, Université de Nantes

Direct production at microscale



Collagen structure 3D bio-printed

Microlight-3D micro-printing machine



Micro-impression by photopolymerisation 2 photons

Source: Microlight, http://www.microlight.fr/fr/master.html

Direct production in other fields

Food - Drugs

Source : https://www.businessinsider.com.au/3d-printed-chocolate-coming-to-european-consumer-market-after-hype-2020-2

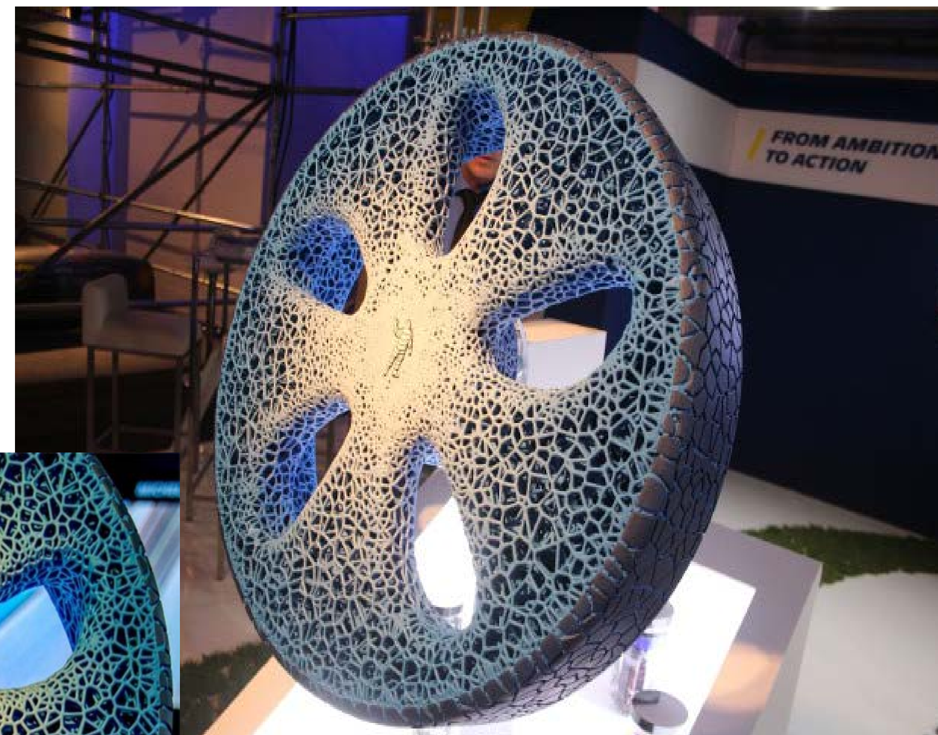
Bio-printing - implants - organs

Source: https://www.3dnatives.com/bio-impression-18052017/

Textiles - Clothes

Source : salon Formnext 2021
Crédit photo : Alain BERNARD

New biodegradable and regenerable materials

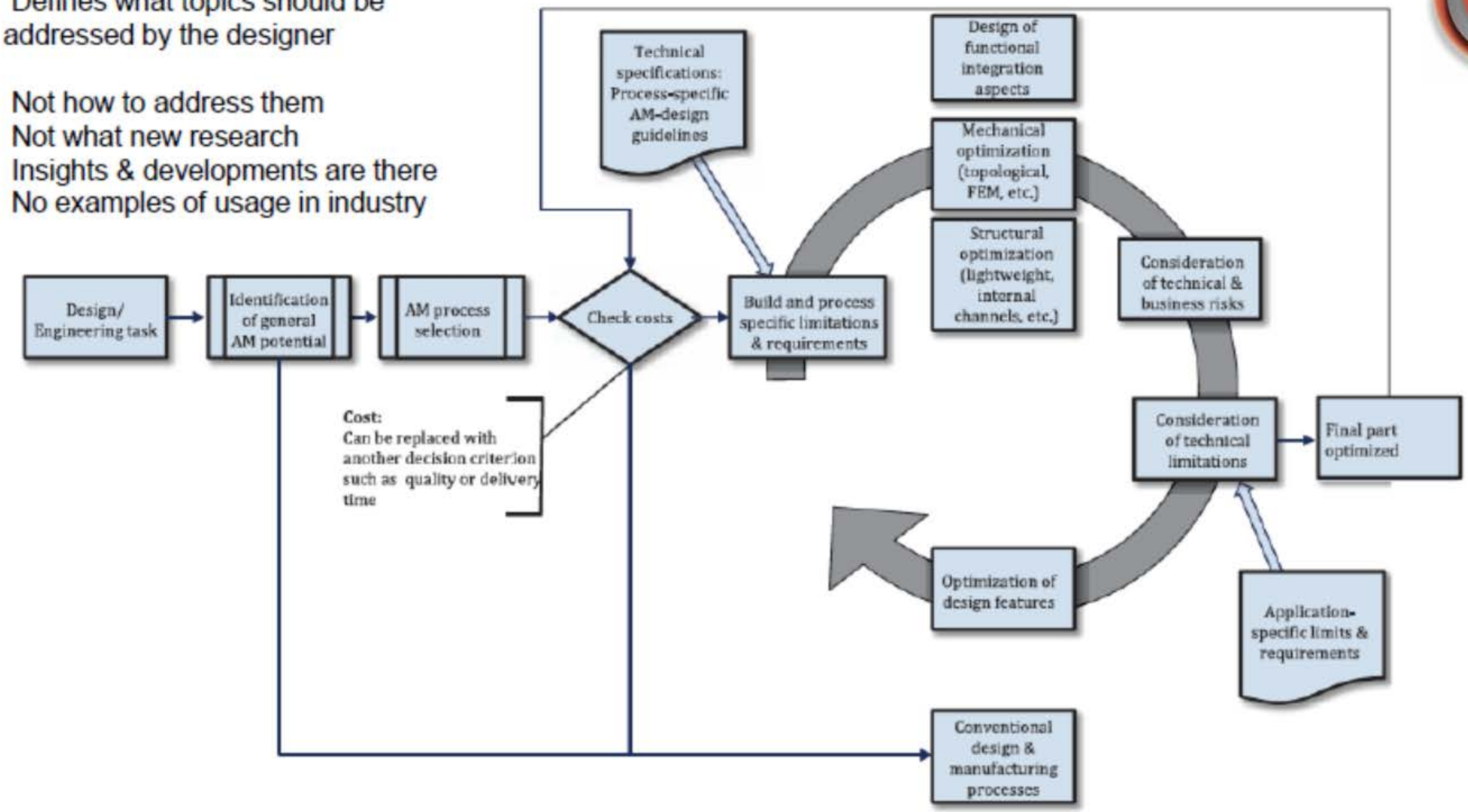


Source : Michelin

DfAM: A methodological approach

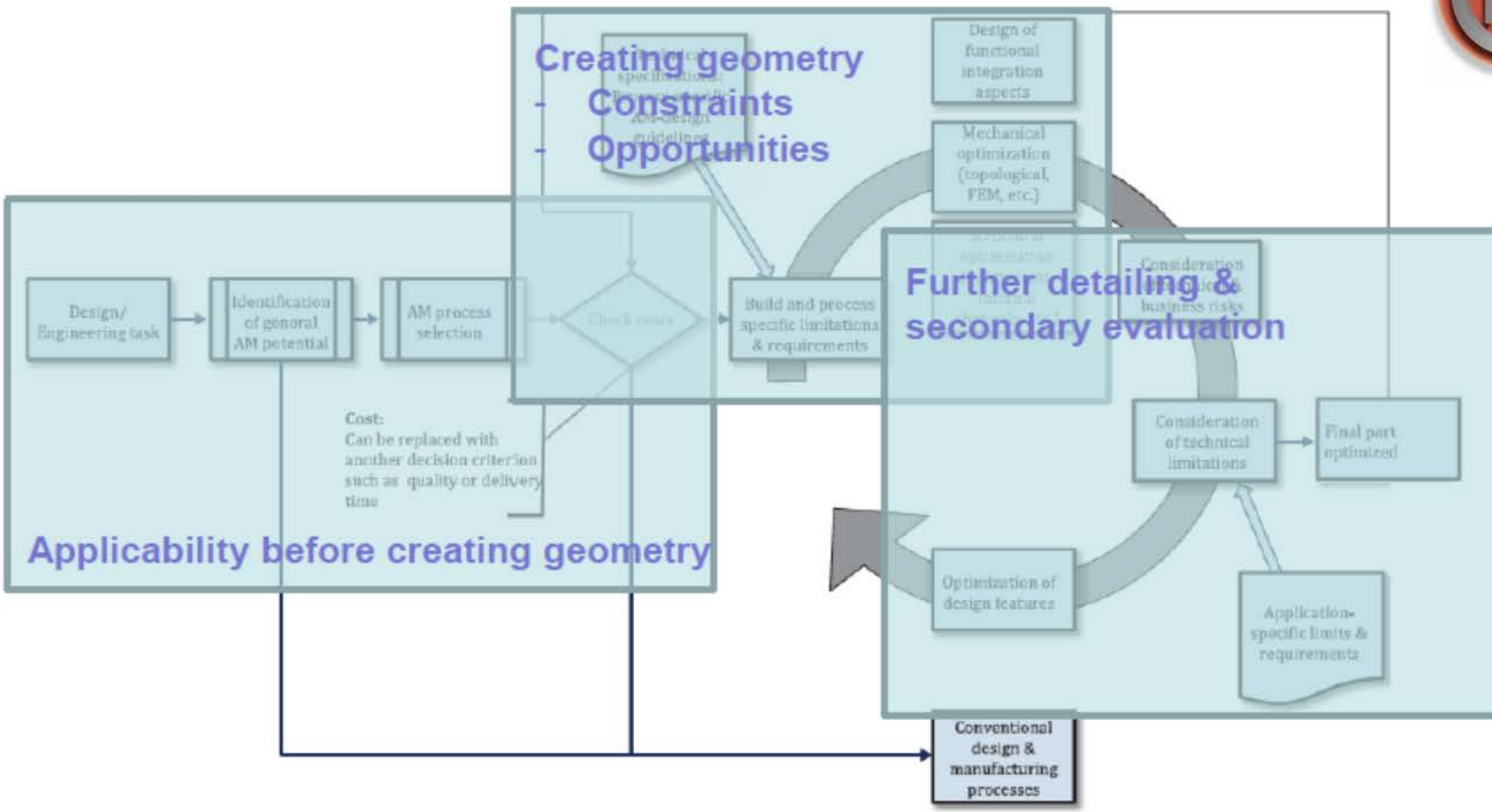
ISO/ASTM 52910:2018
- Defines what topics should be addressed by the designer

- Not how to address them
- Not what new research
- Insights & developments are there
- No examples of usage in industry



Source: CIRP STC Dn Keynote paper, T. Vaneker, A. Bernard et al., 2020

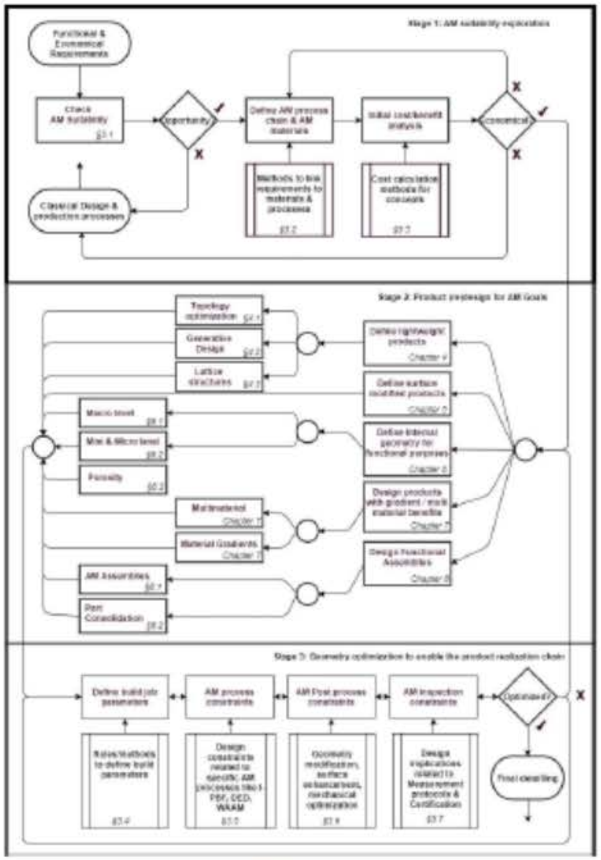
DfAM: A methodological approach



Source: CIRP STC Dn Keynote paper, T. Vaneker, A. Bernard et al., 2020

DfAM: A methodological approach

2. The design framework



Stage 1: Evaluation of AM suitability

AM metal bridge, printed by mx3d (www.mx3d.com) Picture courtesy of M2i (www. m2i.nl)

Stage 2: Product redesign to enhance functionality

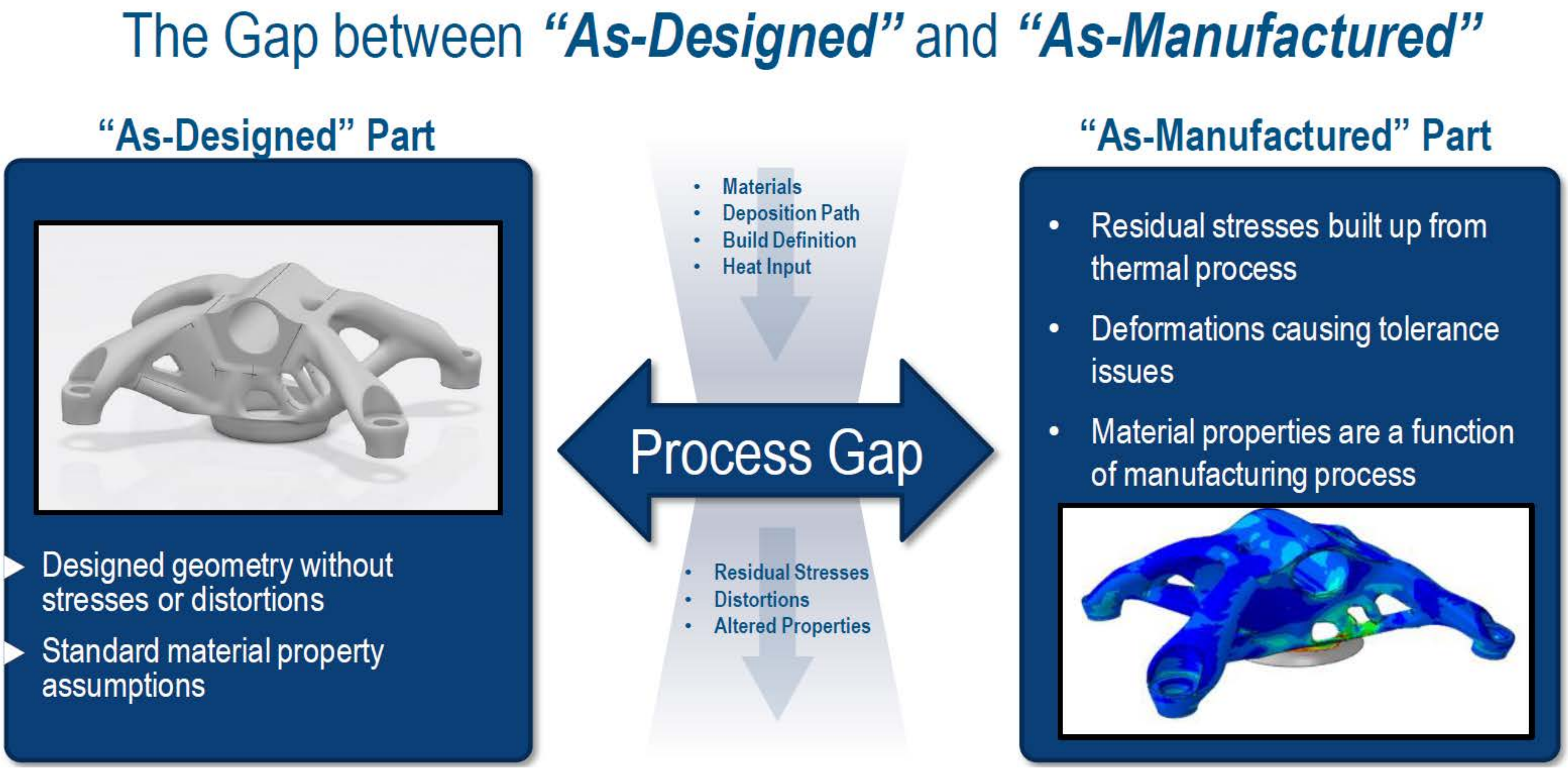
Hull filled with lattice structures [131]

Stage 3: Geometry optimization for the supply chain

Image source: https://metrology.news/metrology-with-high-energy -industrial-computed-tomography/

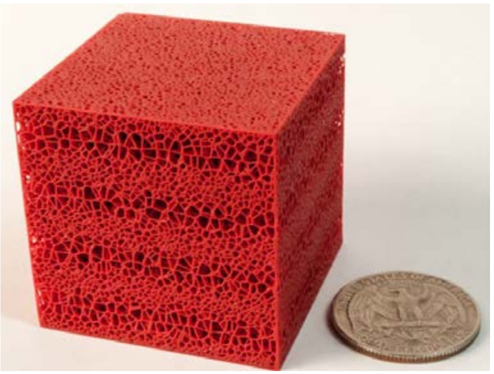
Source: CIRP STC Dn Keynote paper, T. Vaneker, A. Bernard et al., 2020

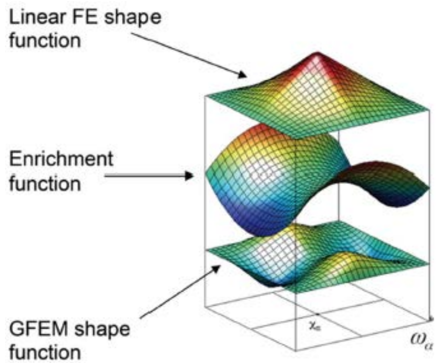
DfAM: Comparison between as-designed and as-manufactured models

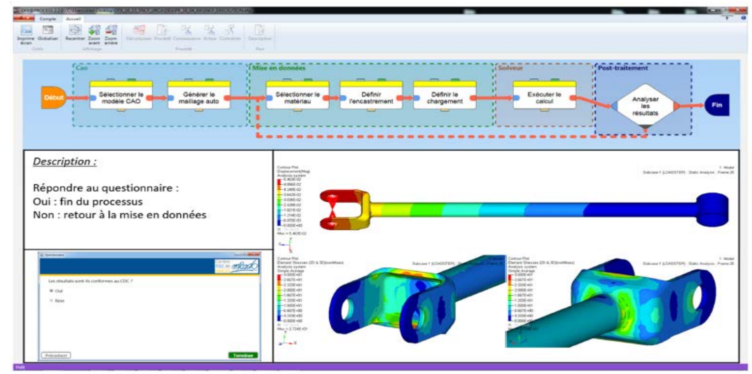


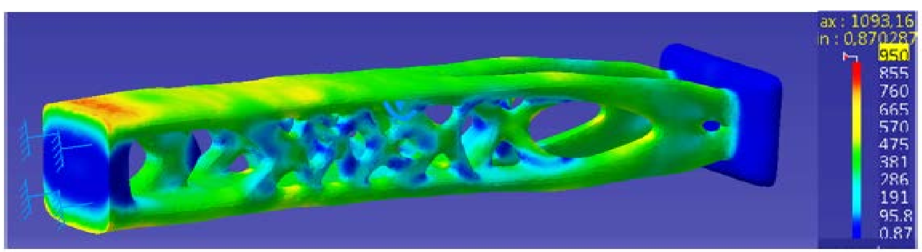
Source: Daniel Pyzak, Dassault Systèmes, Paris, October 2016

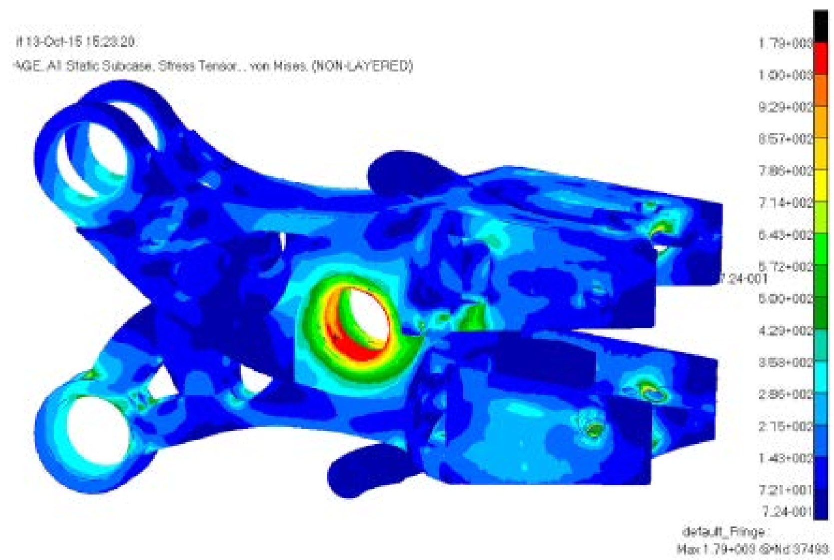
Multiscale modeling and simulation





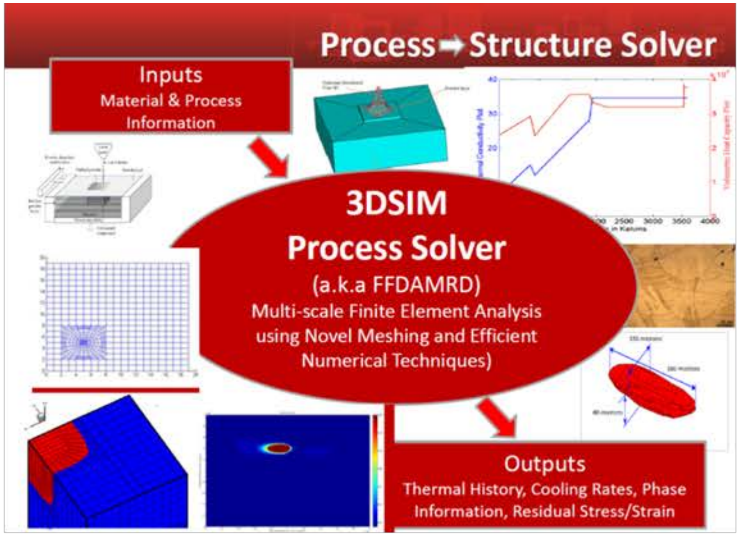


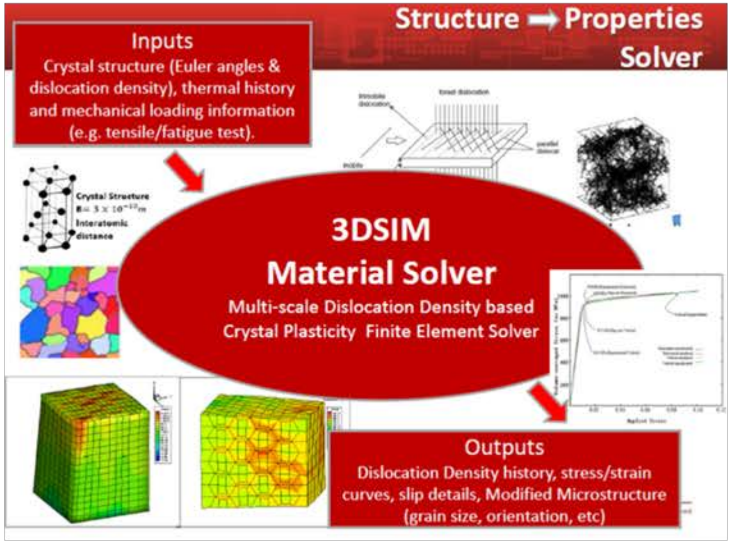




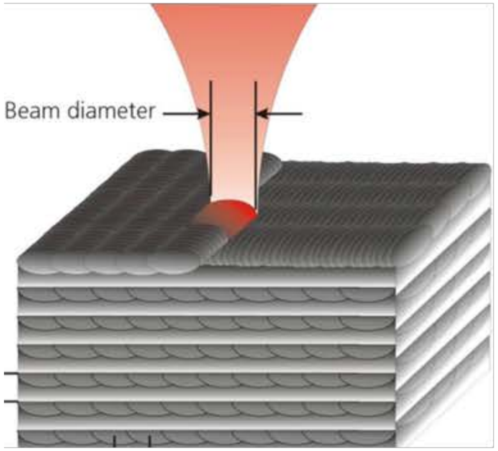
Source: session on digital applications, moderated by Nicolas GARDAN, 21rst EFAM, Paris, 2016

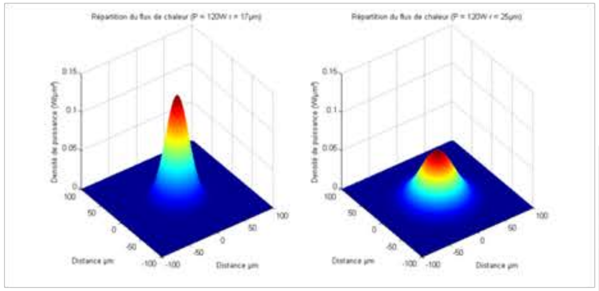
Multiscale modeling and simulation

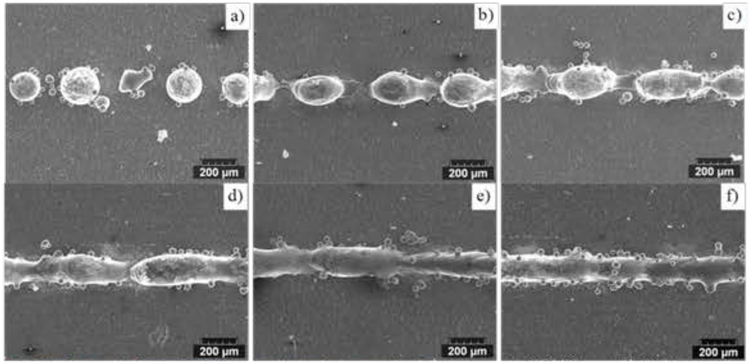




Courtesy: Brent STUCKER, http://3dsim.com





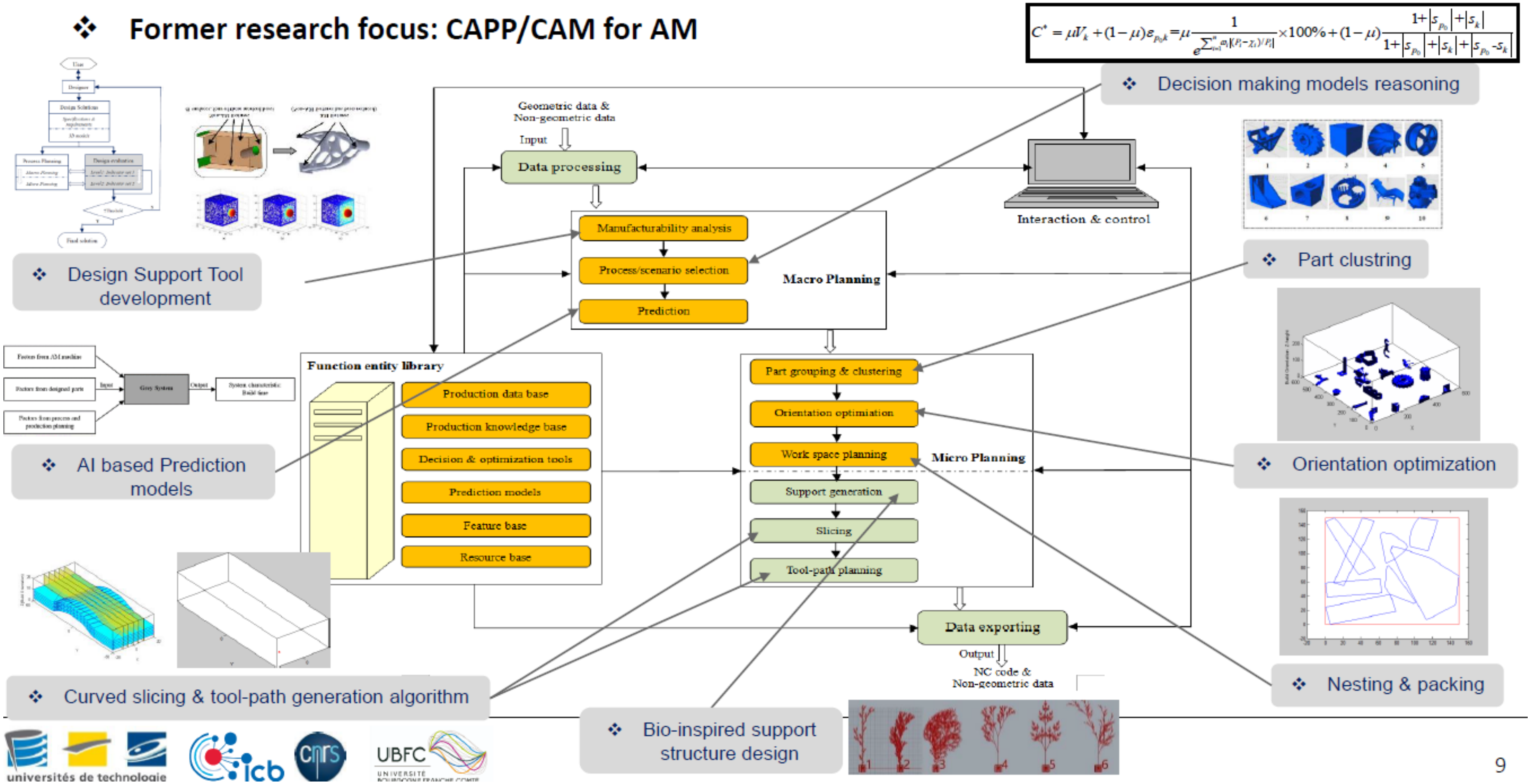


Diminution progressive de la vitesse

a) 0,7 m.s^{-1}, b) 0,47 m.s^{-1}, c) 0,35 m.s^{-1}, d) 0,28 m.s^{-1}, e) 0,23 m.s^{-1}, f) 0,2 m.s^{-1}

Courtesy: Lucas Dembinski, UTBM, IRTES, technical workshop, CNRS, Autrans, october 2015

Beyond CAPP for AM

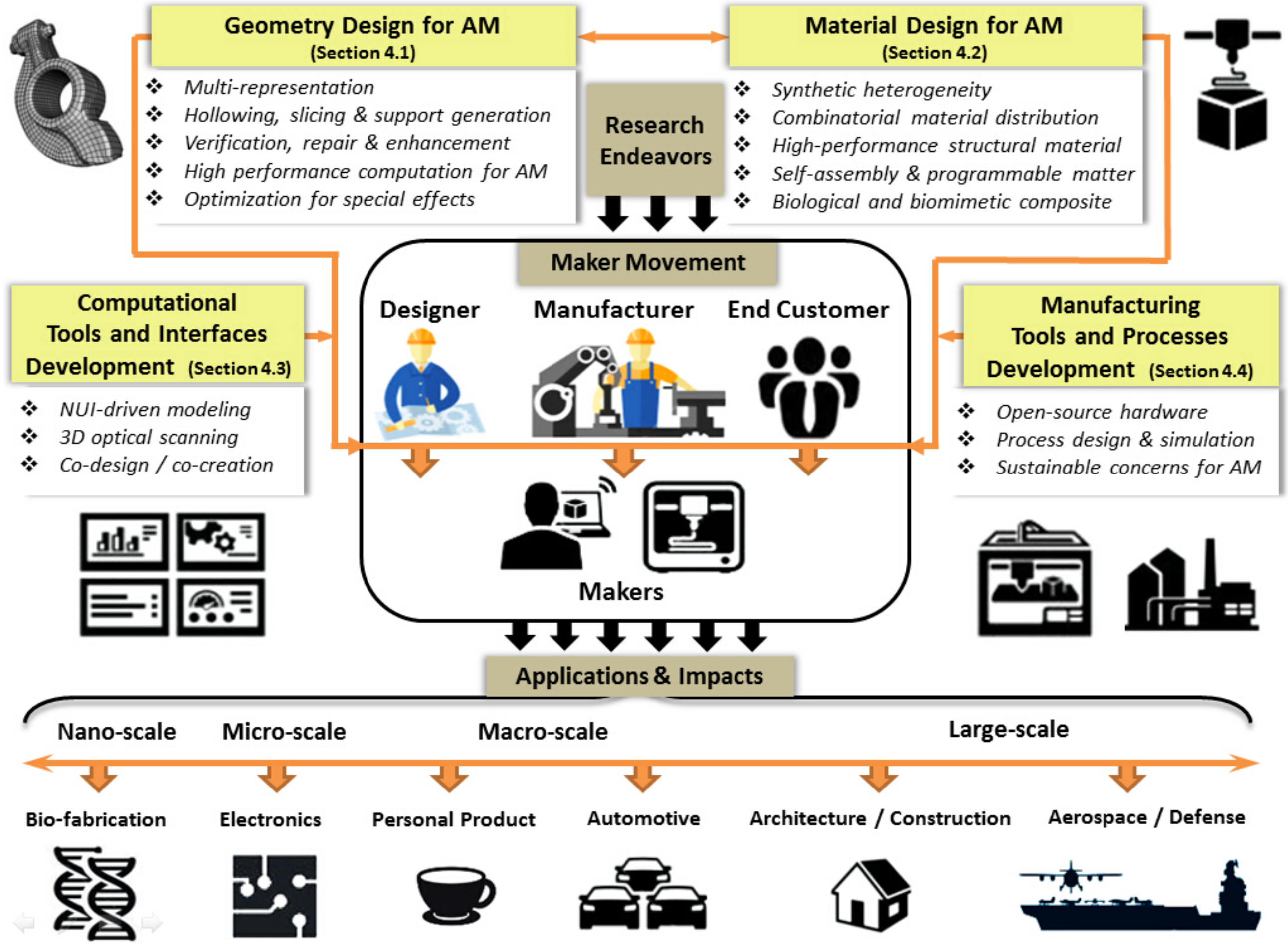


Source : Development of an integrated KBE CAPP system for qualified AM, Y. Zhang (UTBM), A. Bernard (ECN)

Outline of the presentation

- France Additive
- Additive manufacturing: A systemic approach
- Main strengths of Additive Manufacturing
- Main future goals for Additive Manufacturing
- Conclusions

A large impact at all scales and sizes



Source: https://engineering.purdue.edu/cdesign/wp/the-status-challenges-and-future-of-additive-manufacturing-in-engineering/

Next stage of Additive Manufacturing

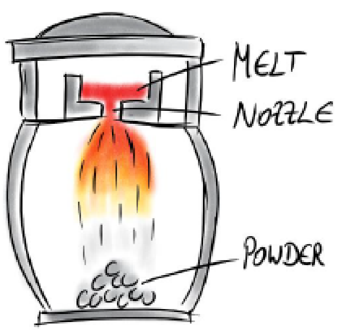
➢ Main expected evolutions

Material → Data preparation and process simulation and modeling → System technology

Material

Enhancement of material portfolio

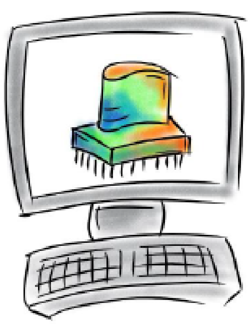
- → High performance materials
- → Multi-material and in-situ alloying



Data preparation and process simulation and modeling

Pre-defined processing strategies

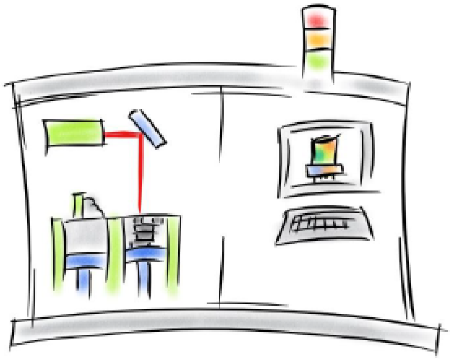
- → Combining data preparation and process simulation
- → Multiscale simulations & iteratively running optimization strategies



System technology

Automation of AM systems with increased build-up rates

- → Multi-beam systems
- → Enlarging build envelopes
- → Beam shaping
- → Integration in process chain

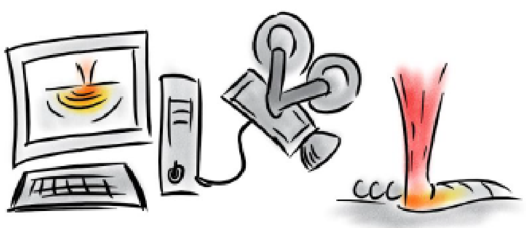


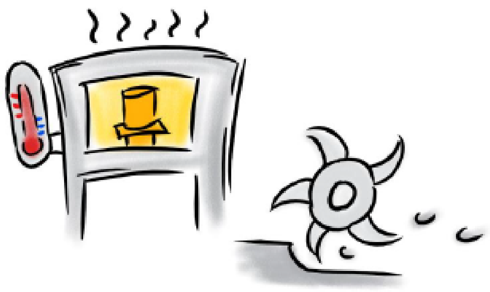
Source : Laser based Additive Manufacturing in industry and academia, M. Schmidt at al., Cross-STC Kn, CIRP Annals, 66/2/561-583

Next stage of Additive Manufacturing

➢ Main expected evolutions

Process monitoring	Quality assurance	Post-processing
Development of closed loop feedback control systems	Development of in-process quality assurance	Individualized post-processing
→ Prediction of process irregularities → Adjusting the processing strategy in-situ	→ From data preparation & simulation to post-processing → Documentation and non-destructive testing	→ Adjusting final part properties → Safe and automated routines for part finishing





Source : Laser based Additive Manufacturing in industry and academia, M. Schmidt at al., Cross-STC Kn, CIRP Annals, 66/2/561-583

A new publication to come

ELSEVIER

Contents lists available at SciVerse ScienceDirect

CIRP Journal of Manufacturing Science and Technology

Vision on metal additive manufacturing: Developments, challenges and future trends

Alain Bernard[(a)], Jean-Pierre Kruth[(b)], Jian Cao[(c)], Gisela Lanza[(d)], Stefania Bruschi[(e)], Marion Merklein[(f)], Tom Vaneker[(g)], Michael Schmidt[(h)], John W. Sutherland[(i)], Alkan Donmez[(j)], Eraldo J. da Silva[(k)]

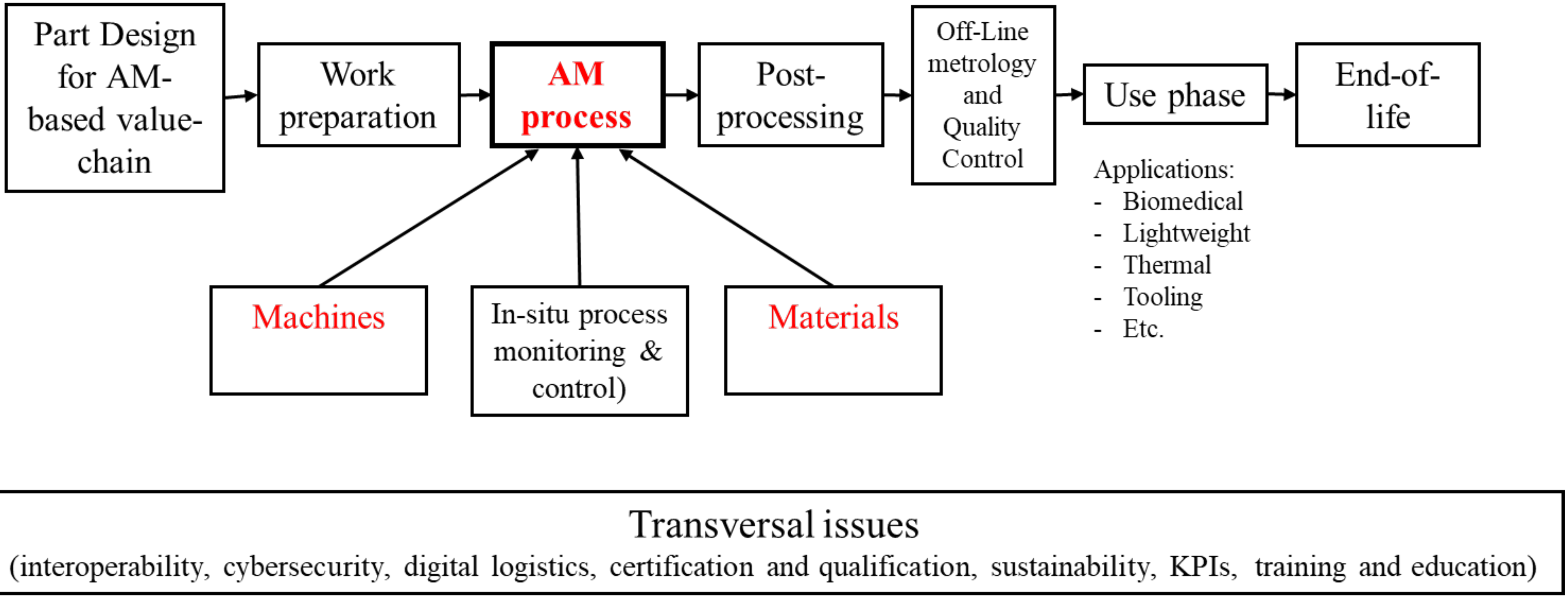
(a) *Nantes Université, Ecole Centrale de Nantes, Laboratoire des Sciences du Numérique de Nantes UMR CNRS 6004, Nantes, France*
(b) *KU Leuven, Department of Mechanical Engineering, Member of Flanders Make, Leuven, Belgium*
(c) *Department of Mechanical Engineering, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3111, USA*
(d) *wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Kaiserstraße 12, 76131 Karlsruhe, Germany*
(e) *Dept. of Industrial Engineering, University of Padova, via Venezia 1, 35131, Padova*
(f) *Institute of Manufacturing Technology, Friedrich-Alexander-Universität Erlangen-Nürnberg, Egerlandstraße 13, 91058 Erlangen, Germany*
(g) *Department of Design, Production and Management, University of Twente, Drienerlolaan 5, 7522 NB Enschede, Netherlands.*
(h) *Institute of Photonic Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Konrad-Zuse-Str. 3/5, 91052 Erlangen, Germany*
(i) *School of Environmental and Ecological Engineering, Purdue University, West Lafayette, IN 47907, USA*
(j) *Engineering Laboratory, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899, USA*
(k) *University of São Paulo, São Carlos School of Engineering, Av. Trabalhador São-carlense, 400. 13566-590, São Carlos-SP, Brazil.*

Abstract: Additive Manufacturing (AM) is one of the innovative technologies to fabricate components, parts, assemblies or tools in various fields of application due to its main characteristics such as direct digital manufacturing, ability to offer both internal and external complex geometries without additional cost, and the potential of varying materials at the voxel level. However, despite high anticipations, AM as a real revolution for serial production of metal components has yet to be seen, mostly due to lacks of fundamental understanding, design engineering tools, and the global robustness of the value chains. This paper aims to provide a vision about the future of metal AM based on the collective knowledge of all ten scientific and technical committees of the International Academy of Production Engineering (CIRP).

Additive Manufacturing, 3D printing, Innovative manufacturing technologies, metal AM processes

Source: Vision on metal additive manufacturing: Developments, challenges and future trends, Bernard et al., resubmitted CIRP JMST

Systemic integration for AM



Source: Vision on metal additive manufacturing: Developments, challenges and future trends, Bernard et al., resubmitted CIRP JMST

Benefits/Weaknesses of AM

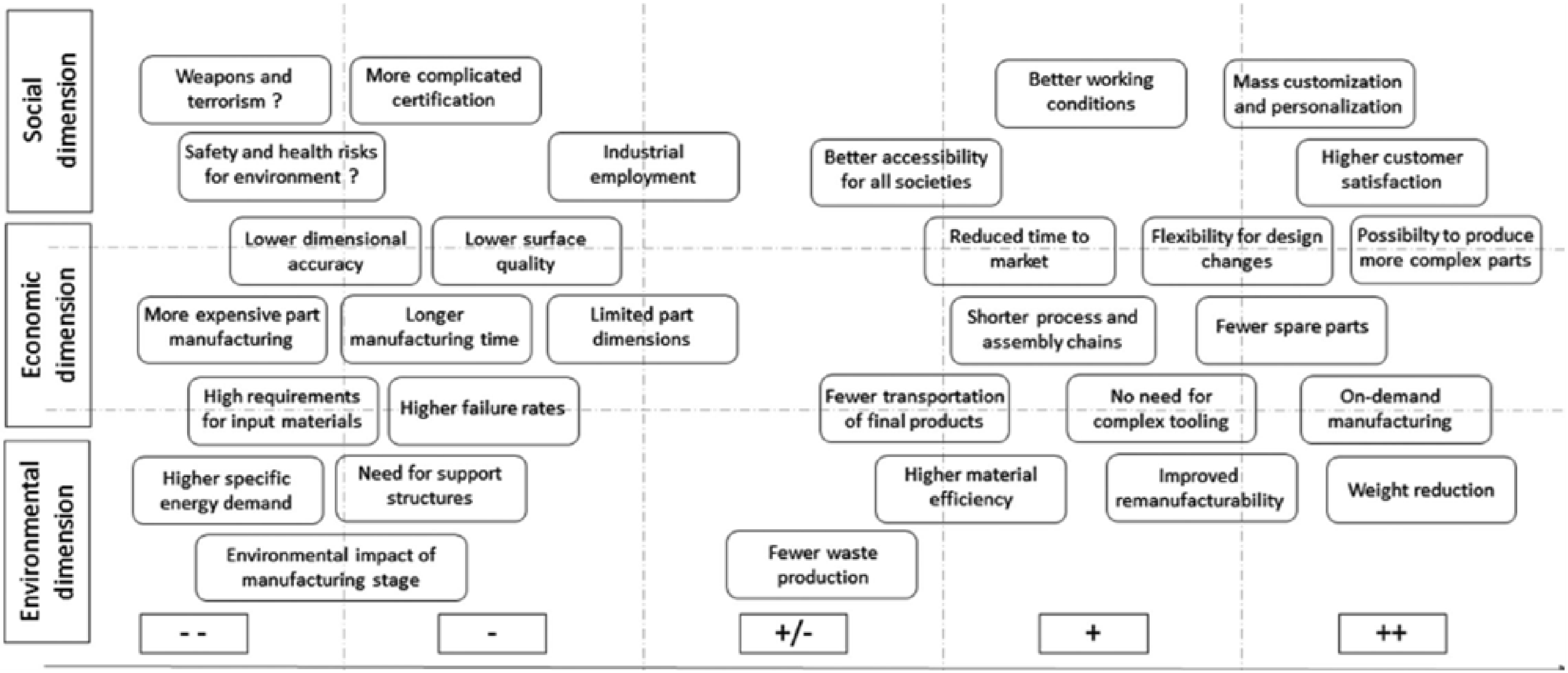


Figure §8.1 Benefits (++) and weaknesses (–) of additive manufacturing processes compared to conventional manufacturing processes [Kellens et al., 2017].

Source: Vision on metal additive manufacturing: Developments, challenges and future trends, Bernard et al., resubmitted CIRP JMST

Sustainability benefits using AM

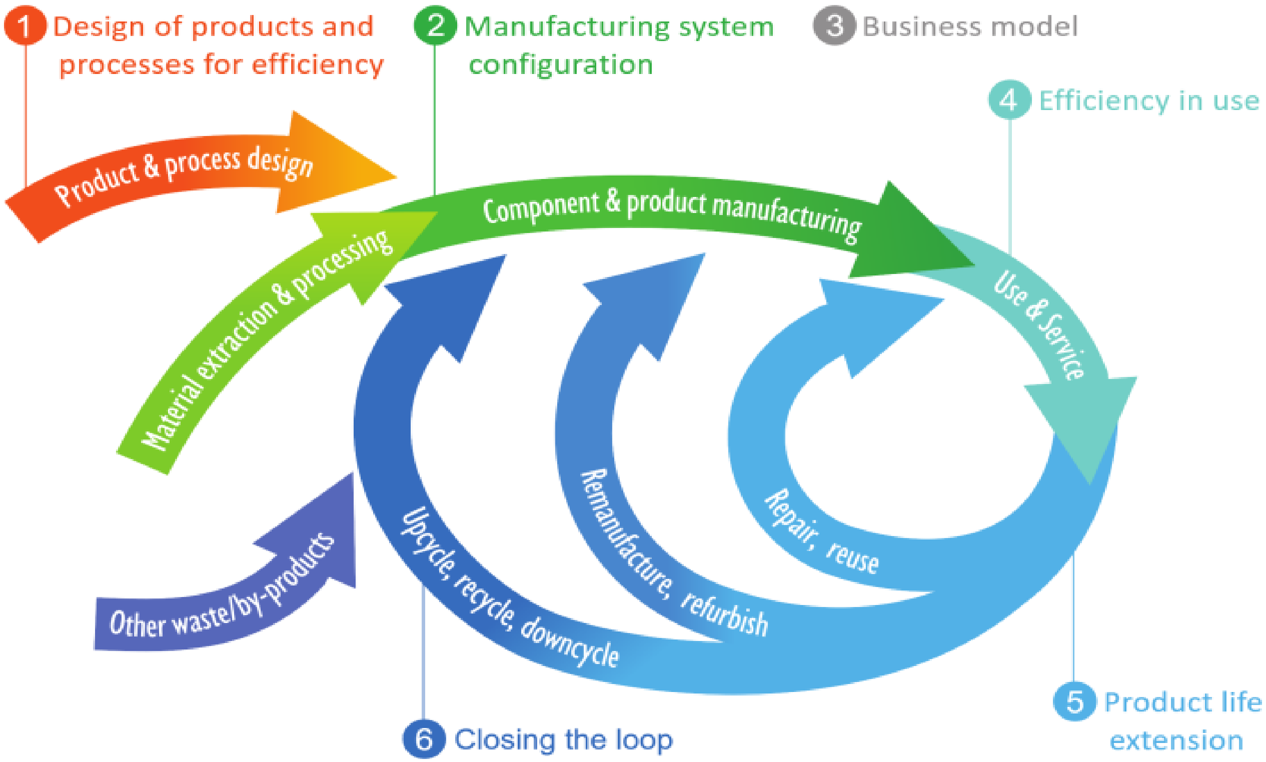
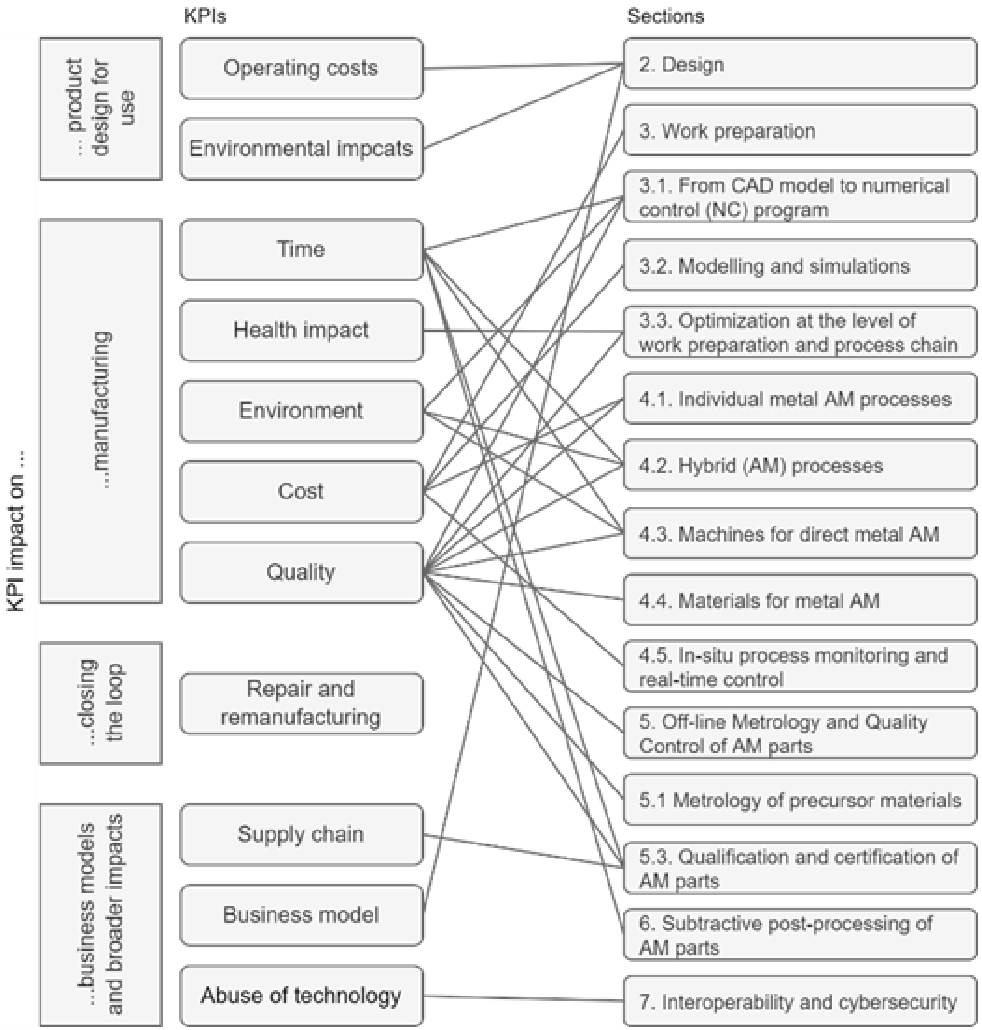


Figure §8.2 Six areas for sustainability benefits across product life cycle using AM [Despeisse et al., 2017]).

Source: Vision on metal additive manufacturing: Developments, challenges and future trends, Bernard et al., resubmitted CIRP JMST

KPIs across Lifecycle with AM



Source: Vision on metal additive manufacturing: Developments, challenges and future trends, Bernard et al., resubmitted CIRP JMST

Main strategic challenges

An industrial challenge

An environmental challenge

A societal challenge

A disrupted industrial value chain. AM is intended to:

- Increase performances
- Decrease costs
- Reduce Time to market

A profound reorganisation of the 'supply chain'.
Production:

- On-demand
- Close to end-use
- With the right material

Redistribution of added value across the value chain :

- National sovereignty
- Relocalisation
- Train and retain talents

Source: France Additive

CENTRALE NANTES

LS2N LABORATOIRE DES SCIENCES DU NUMÉRIQUE DE NANTES

FRANCE ADDITIVE FILIÈRE IMPRESSION 3D

ACADÉMIE DES TECHNOLOGIES
POUR UN PROGRÈS RAISONNÉ CHOISI PARTAGÉ

Une vision systémique de la fabrication additive métallique : développements, challenges et tendances pour le futur

Thank you for your kind attention.
Any question?

alain.bernard@ec-nantes.fr