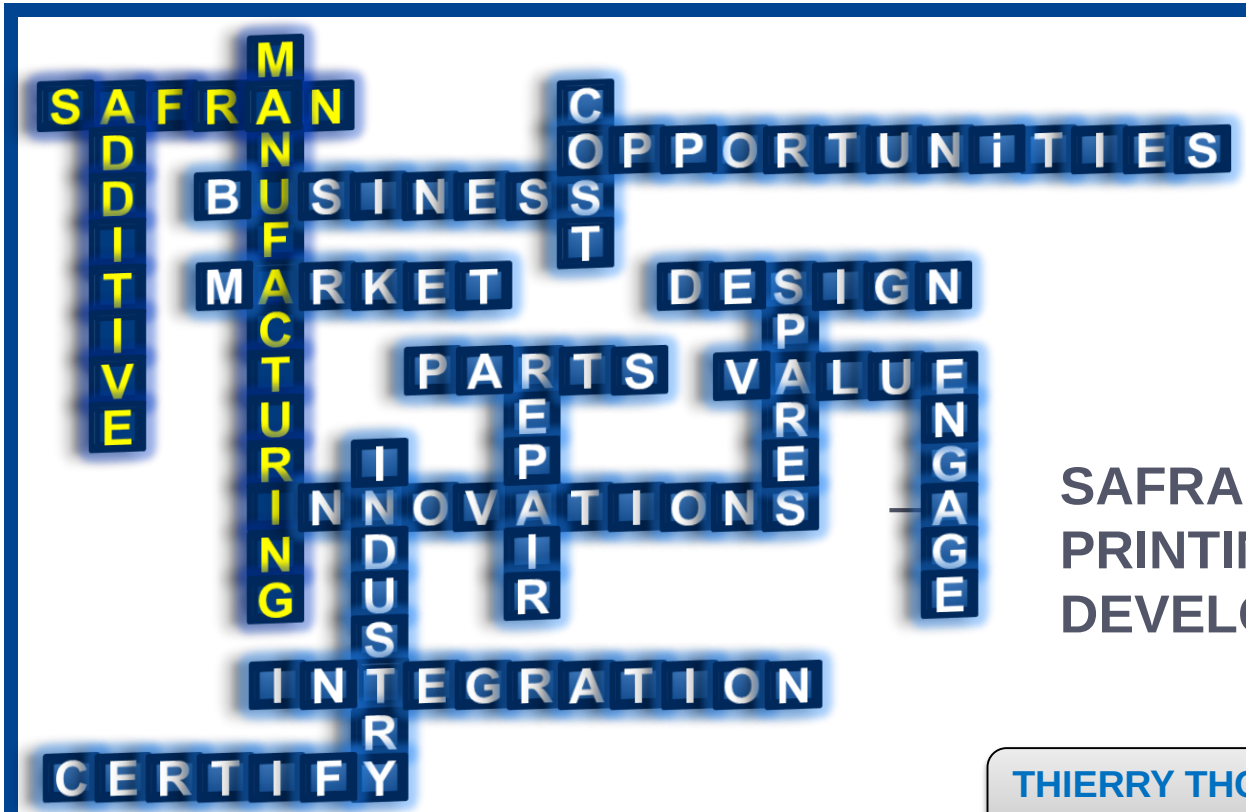


SAFRAN'S VISION OF 3D PRINTING APPLICATION DEVELOPMENT

THIERRY THOMAS
VP SAFRAN ADDITIVE MANUFACTURING

SAFRAN

SAFRAN's Vision of 3D Printing Application Development

SAFRAN

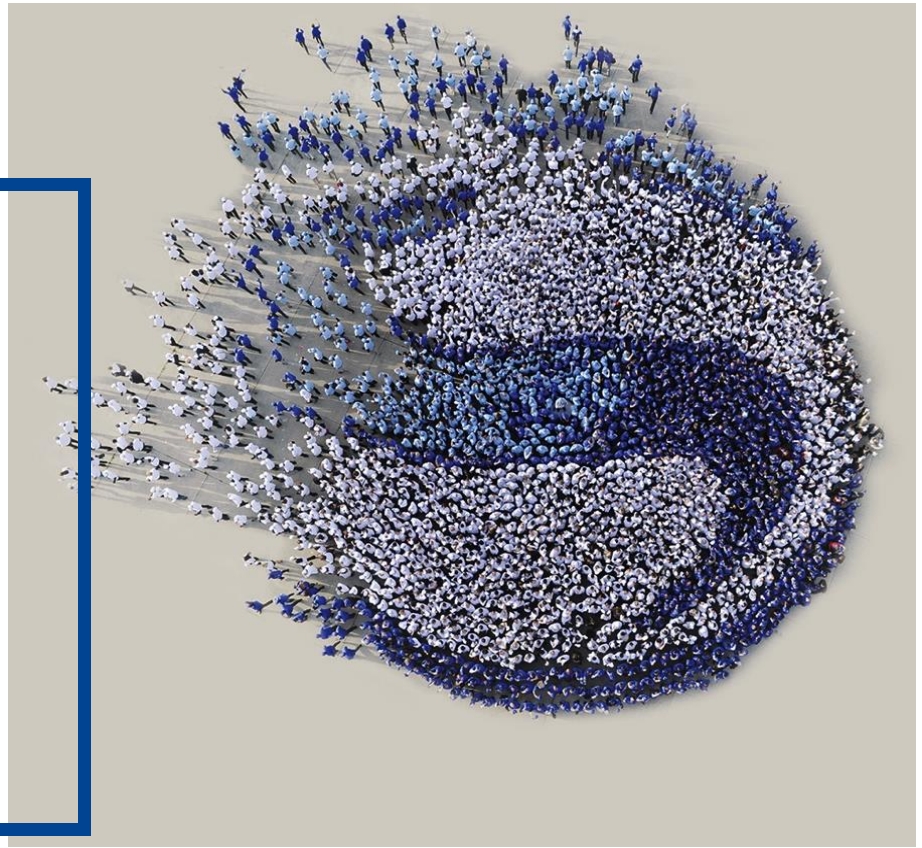
WHO ARE WE, KEY FIGURES, IMPORTANCE OF TECHNOLOGY AND INNOVATION FOR US;

CHALLENGES AND OPPORTUNITIES OF ADDITIVE MANUFACTURING

ADDITIVE MANUFACTURING, A MUST FOR THE FUTURE OF MANUFACTURING

CONCLUSION

SAFRAN AT A GLANCE



AN INTERNATIONAL HIGH-TECHNOLOGY GROUP

3 CORE BUSINESSES:
Aerospace
Defense
Security

66,500 EMPLOYEES
in more than
60 COUNTRIES

€15.8 BILLION
in sales*

€2.4 BILLION
in adjusted recurring operating income*

€1.7 BILLION
in R&D expenditures*, equal to nearly 11% of sales

Over **850 INITIAL PATENTS**
filed in 2016

*2016

SAFRAN: TECHNOLOGY THAT BENEFITS OUR DAILY LIVES

1 SINGLE-AISLE COMMERCIAL JET TAKES OFF every **2 SECONDS,** powered by our engines*

MORE THAN 40,000 LANDINGS a day using our equipment

MORE THAN 76 SUCCESSFUL ARIANE 5 LAUNCHES in a row**

3,000 MILITARY AIRCRAFT fitted with our inertial navigation systems

1 OUT OF EVERY 3 HELICOPTER TURBINE ENGINES sold worldwide

2.8 BILLION ID DOCUMENTS delivered worldwide

OVER 35,000 POWER TRANSMISSIONS totaling over 850 million flight-hours

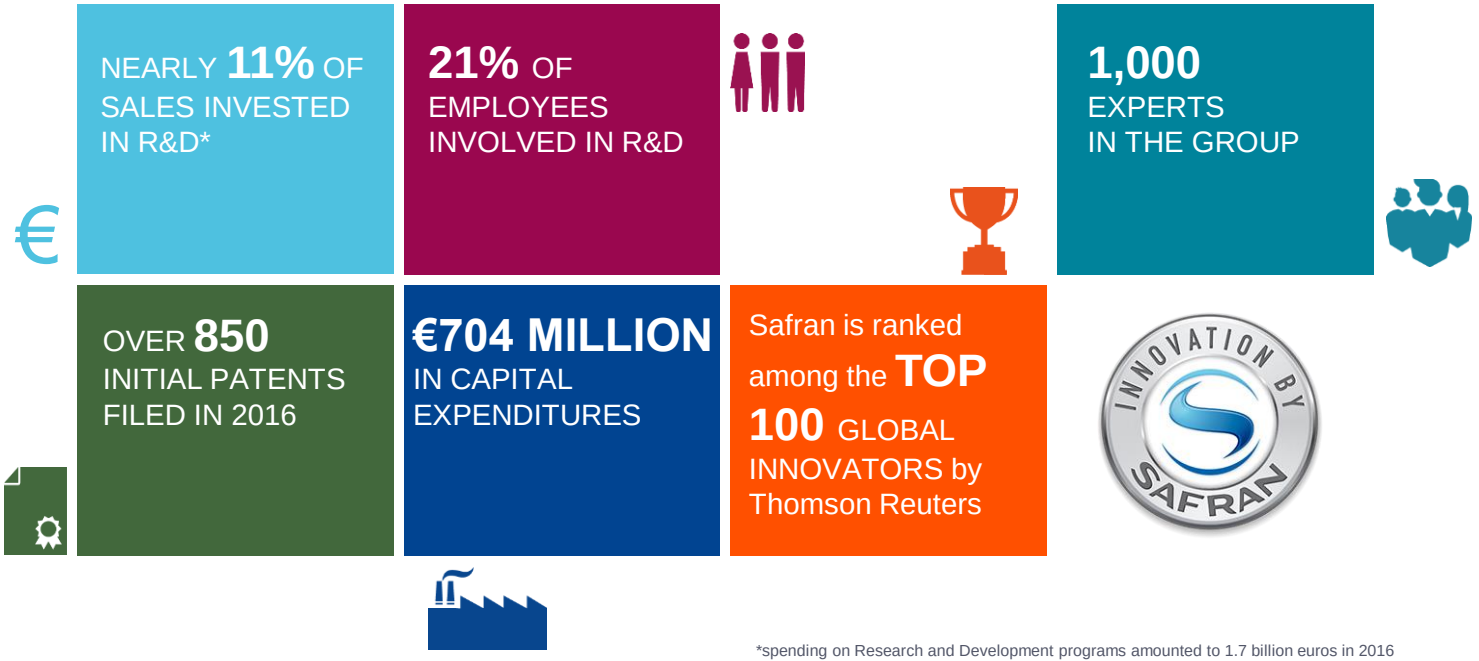
17,300 NACELLE COMPONENTS in service

500 KM OF ELECTRICAL WIRING on an Airbus A380

*in partnership with GE, through CFM International
**in partnership with Airbus Group, through Airbus Safran Launchers

INNOVATION AT SAFRAN

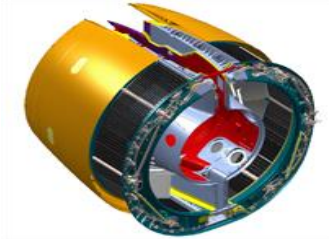
(31/12/2016)



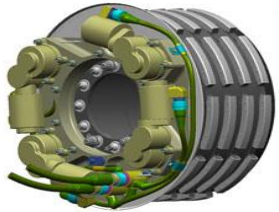
*spending on Research and Development programs amounted to 1.7 billion euros in 2016

SAFRAN, IMPORTANCE OF R&D FOR US

Innovation is at the heart of SAFRAN Products

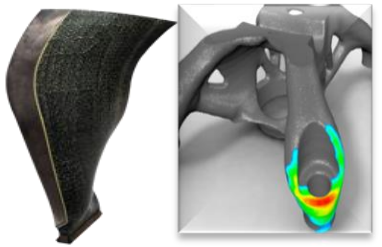


Electrically-actuated A380 /C919 thrust reverser



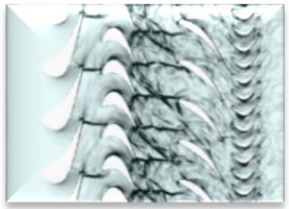
Electrically-actuated carbon brake

Multi-Biometric recognition



3D RTM fan blade

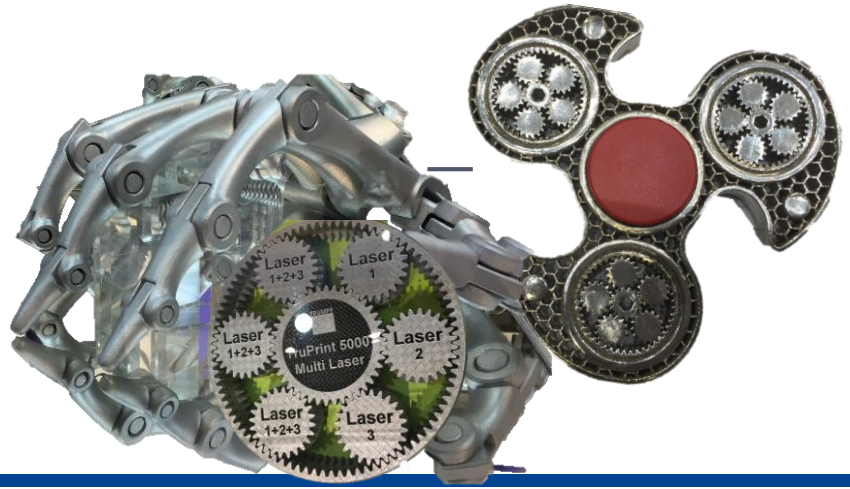
CMC nozzle and combustor



Complex simulations

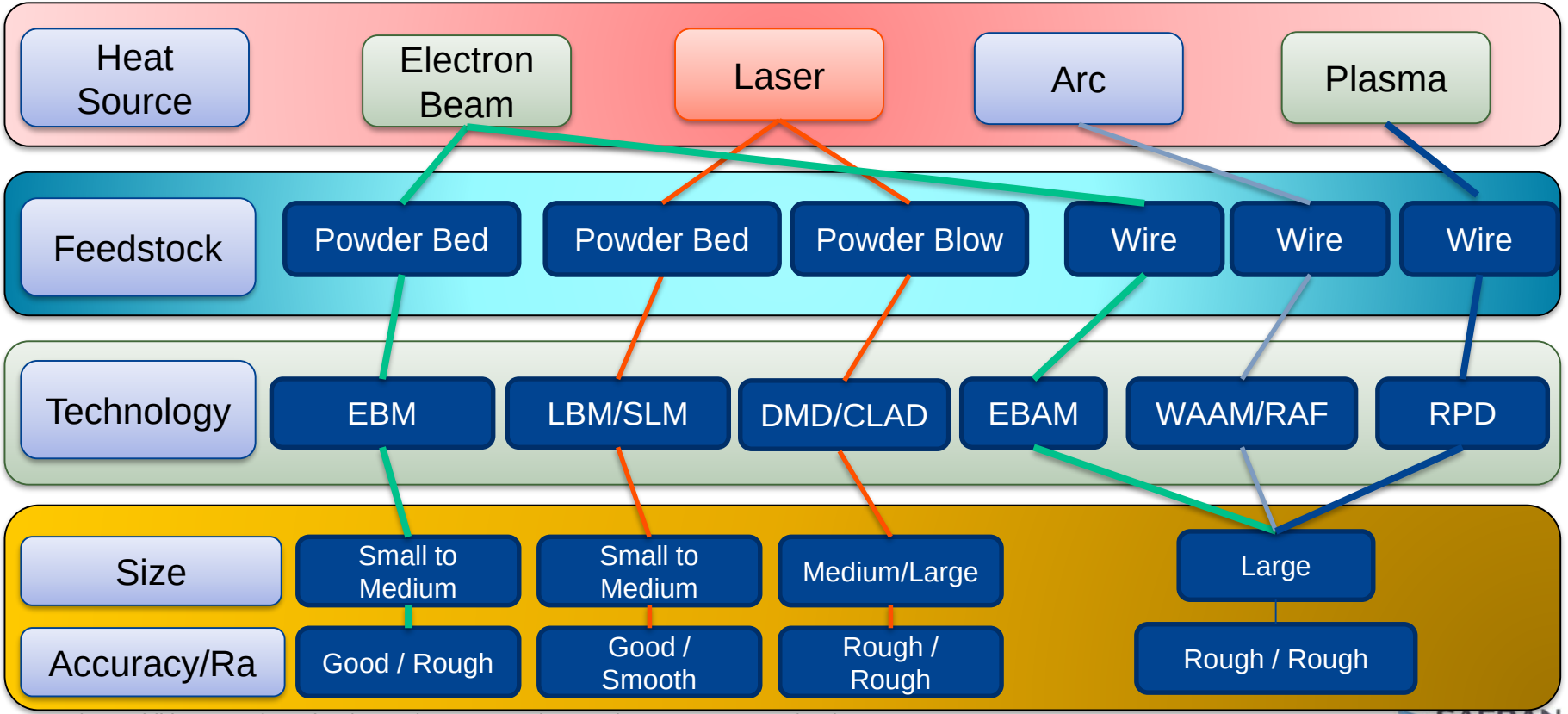
- ➔ R&D investment: **1,7 billion euros in 2016,** more than 11% of revenue
- ➔ **70% of SAFRAN's R&D budget is dedicated** to reducing the environmental impact of air transport

CHALLENGES AND OPPORTUNITIES OF ADDITIVE MANUFACTURING



SAFRAN

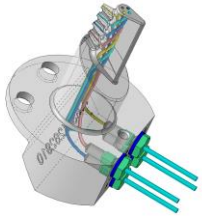
Technologies



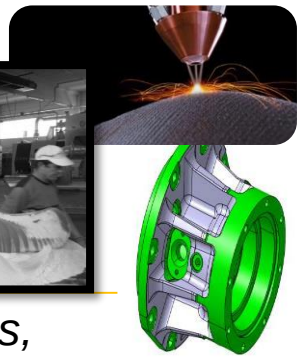
3D AM ENABLES SAFRAN TO CREATE VALUE

Less subassemblies / more complex parts

Reduce weight up to 75%

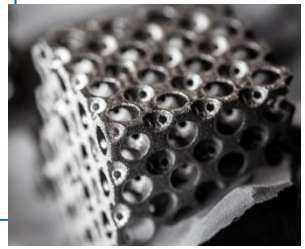


- 4 parts certified and in production
- Non critical parts first
- Hundreds of potential new ones



Tooling, Spares, prototypes → a lot of agility/pro-activity

Development cycle reduced by 30% and Cost

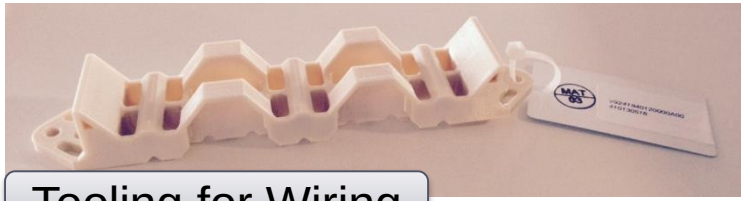


Innovative Repairs solutions

Production cycle down by 40% to 80%

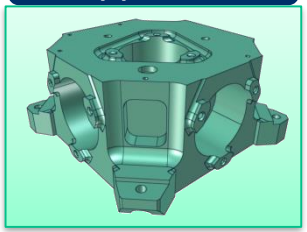
SAFRAN

SAFRAN

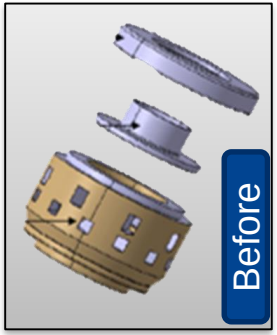


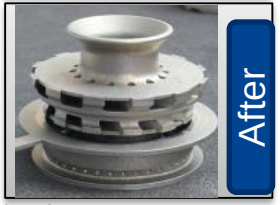
Tooling for Wiring

Support box

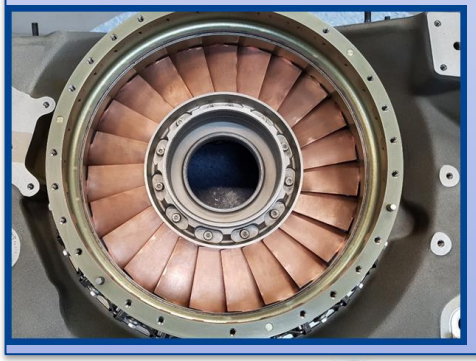


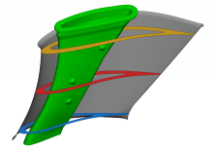
Mirors support





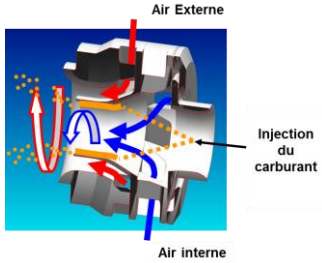
Vanes





Chemise DBP1 Silvercrest (vert)HA188

Inserts



Injectors & Swirlers

SAFRAN

3 SIMULTANEOUS PHASES FOR AN UNIQUE VISION, ENSURING AM DEVELOPMENT

Appropriation: Iso Design

Mature data and ability to certify parts
Mature Supply-chain
Maximise agility offered by AM technologies

Optimisation:

Design for AM, functions integration …
Master powder : chemistry, recycling, productivity, cost
Master the Digital Thread that must be deeply integrated
Process : Quality, process control, cost/productivity, post-fabrication and surface finish

Augmented/ Intelligent Function:

Systemic analysis of complex systems will drive our designs
Multi-material processes will enable complex functions
Integration of Electronic and electrical elements to be matured

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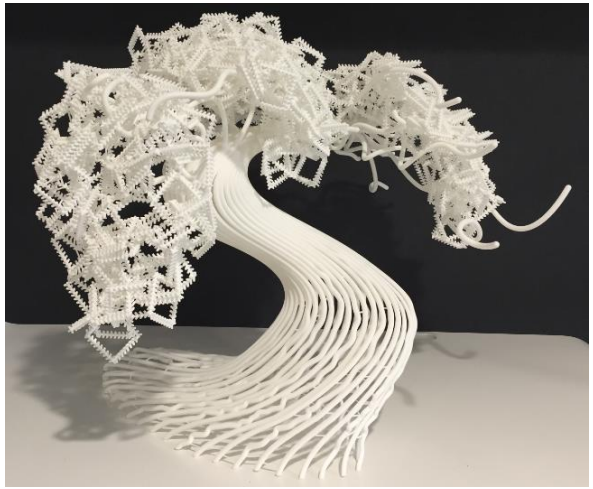

HOW TO MASTER MATERIAL AND PROCESS

—

Through a multiscale approach which combine physic of material – energy interaction, metallurgy and numerical simulation

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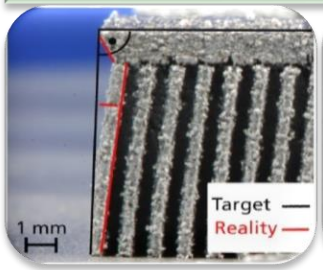
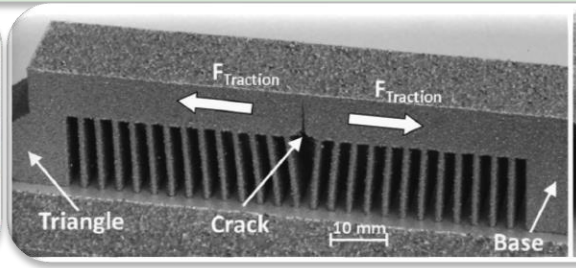
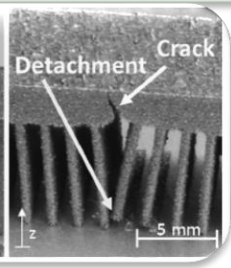
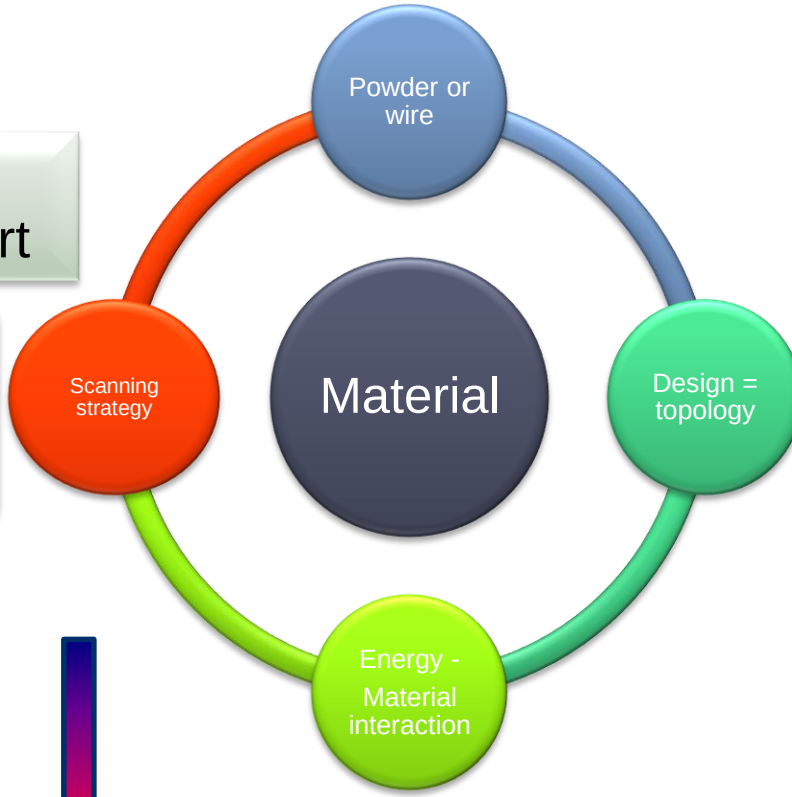
ADDITIVE MANUFACTURING: A NEW PARADIGM

Material = Initial Chemistry + Process
As for composite, material is built with the part

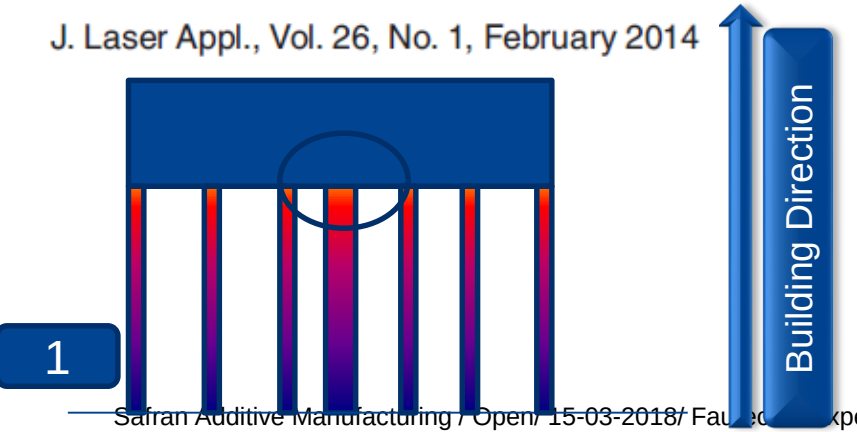








J. Laser Appl., Vol. 26, No. 1, February 2014



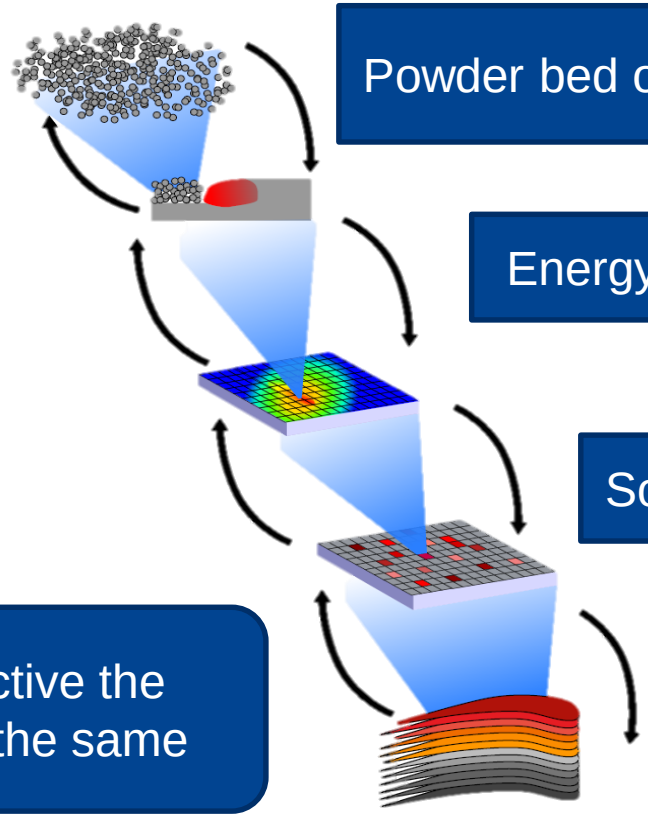
A multiscale approach is needed

To master quality

To master costs

To increase productivity

To maximise performances



Powder bed or flow modelisation

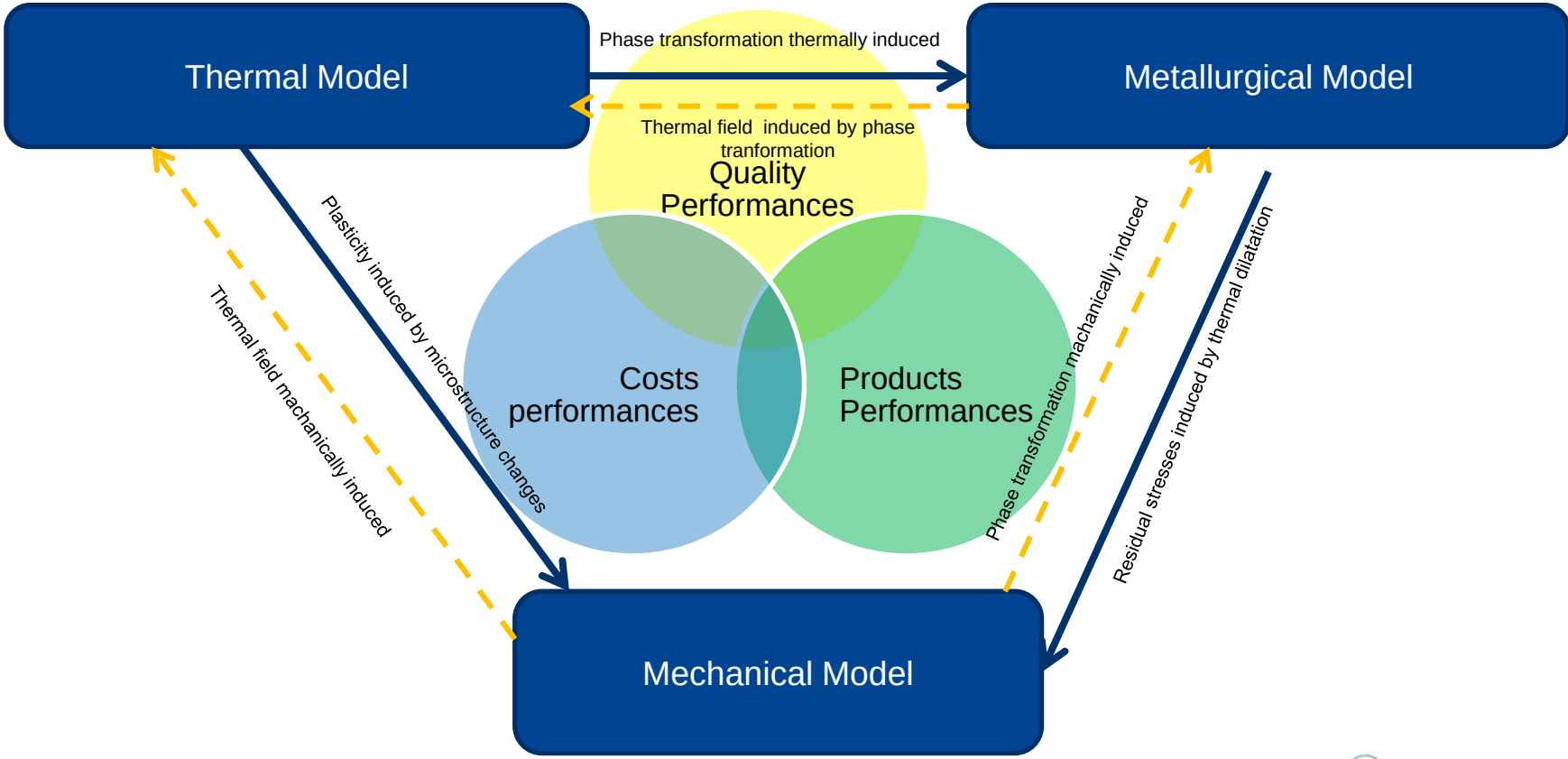
Energy deposition

Solidification process

Layers interaction

Depending on the objective the appropriate scale is not the same

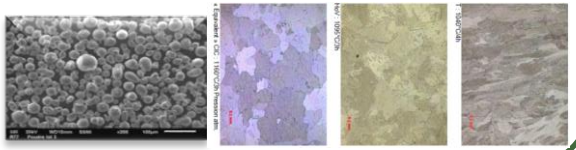
Key Industrial Drivers Vs Scientific & Technical Challenges



5 BUILDINGS BLOCKS TO BE MASTERED for AM process

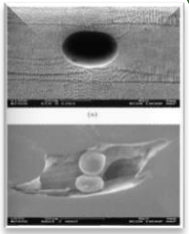
Powder

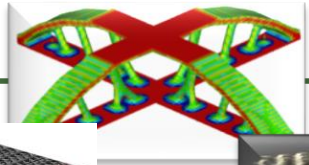
Cost –quality management
Supply-Chain Qualification
Dedicated AM nuances (MFAM)



Process control

Defect library
Key process parameters
In situ process control
Sanction & Control loop process
Performant NDT



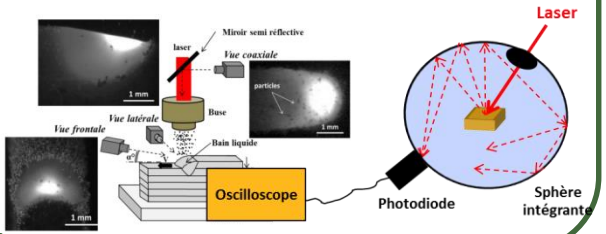


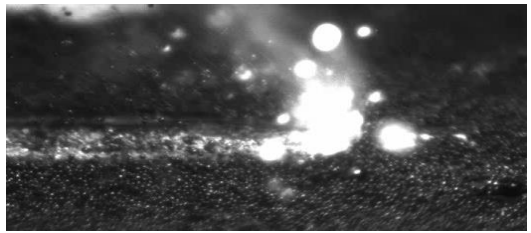
DFAM (Design for AM)

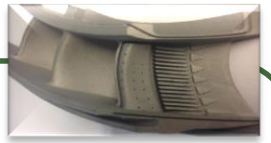
Optimisation Topologic and Parametric
Design to manufacturing and to cost
Function Integration
Pyramid tests & Certification

Energy-material Interaction

Defect library
Thermal field modeling/steering
New energy sources

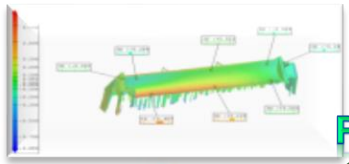






Simulation

Process Simulation & Optimisation
Multi-scale & Multi-physics simulation
Part simulation

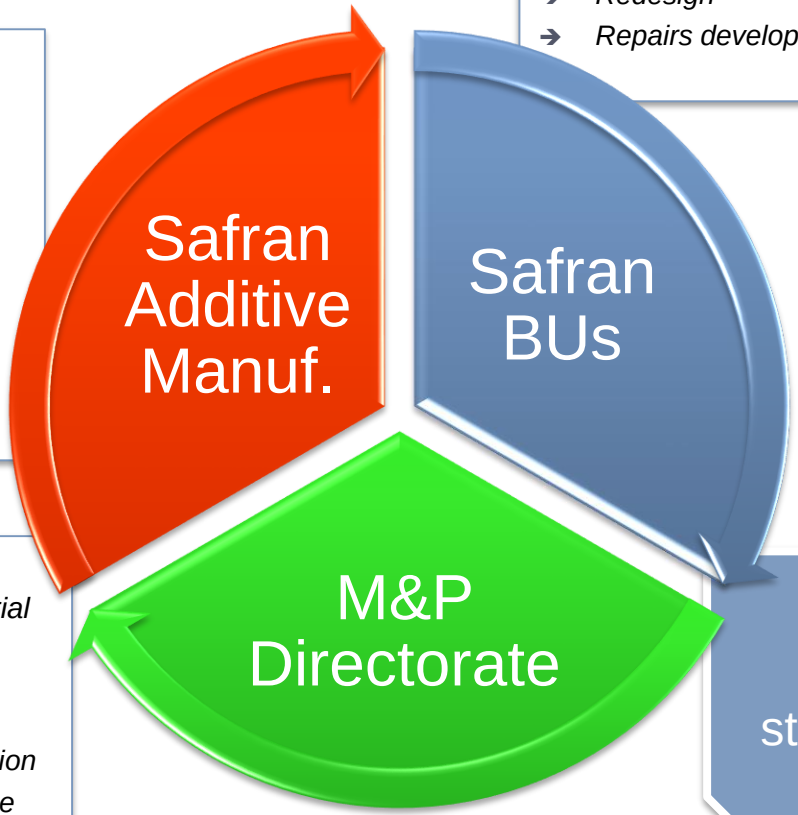


SAFRAN AM Organisation

Plate-forme of Safrantech in charge of :

- *Safran's AM road-map management*
- *R&T from TRL 1 up to 6 to master and push state of the art*
- *Tools and new materials developments*
- *Build partnerships : industrial and academic*
- *Support certification*
- *Support industrialisation (powders, machines evaluations, training, …)*

- *Proof Of Concept*
- *IndustrialisationTRL 5→9 (OEM et Spares)*
- *Redesign*
- *Repairs developments*



Supported by a strong gouvernance

DM&P/AM segment gather Safran's AM material specialits and experts :

- *Define Safran's material standards*
- *Provide support for qualification/certification/industrialisation*
- *Lead and Validate material datas base*

FROM PROTOTYPE TO SERIAL PRODUCTION

There is just one question …

Why after 8-10 years of development are there so few parts in serial production ?

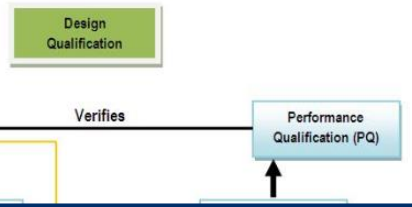
Current aeronautical industry situation

We are here

Design & certification

Industrialisation

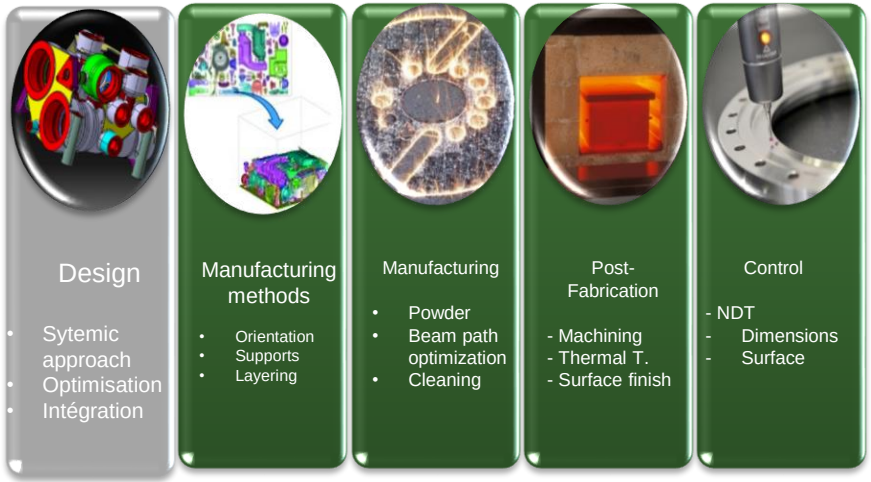
Serial Production



COST is today the first blocker for AM development

Additive Manufacturing Value Chain : it is not just about printing

Fom Design to Manufacturing



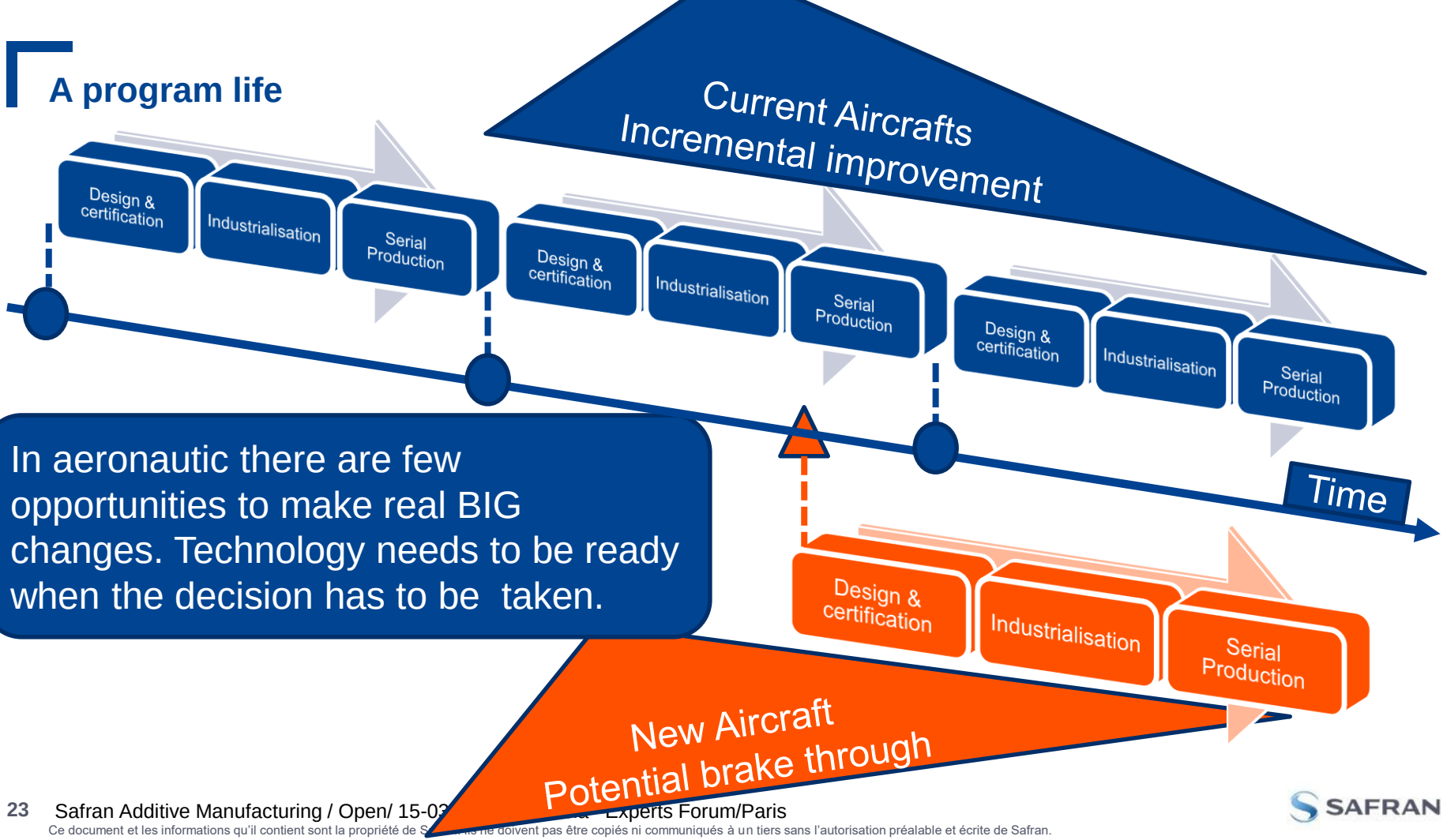
Projected costs show a cost decrease of 40% in the next 5 Years and 60% in the next 10

(ex: Multi-lasers Machines, energy-sources, bigger machines, control in situ, automatisation, multi-maning, …)

Post fabrication and control have to be addressed quickly

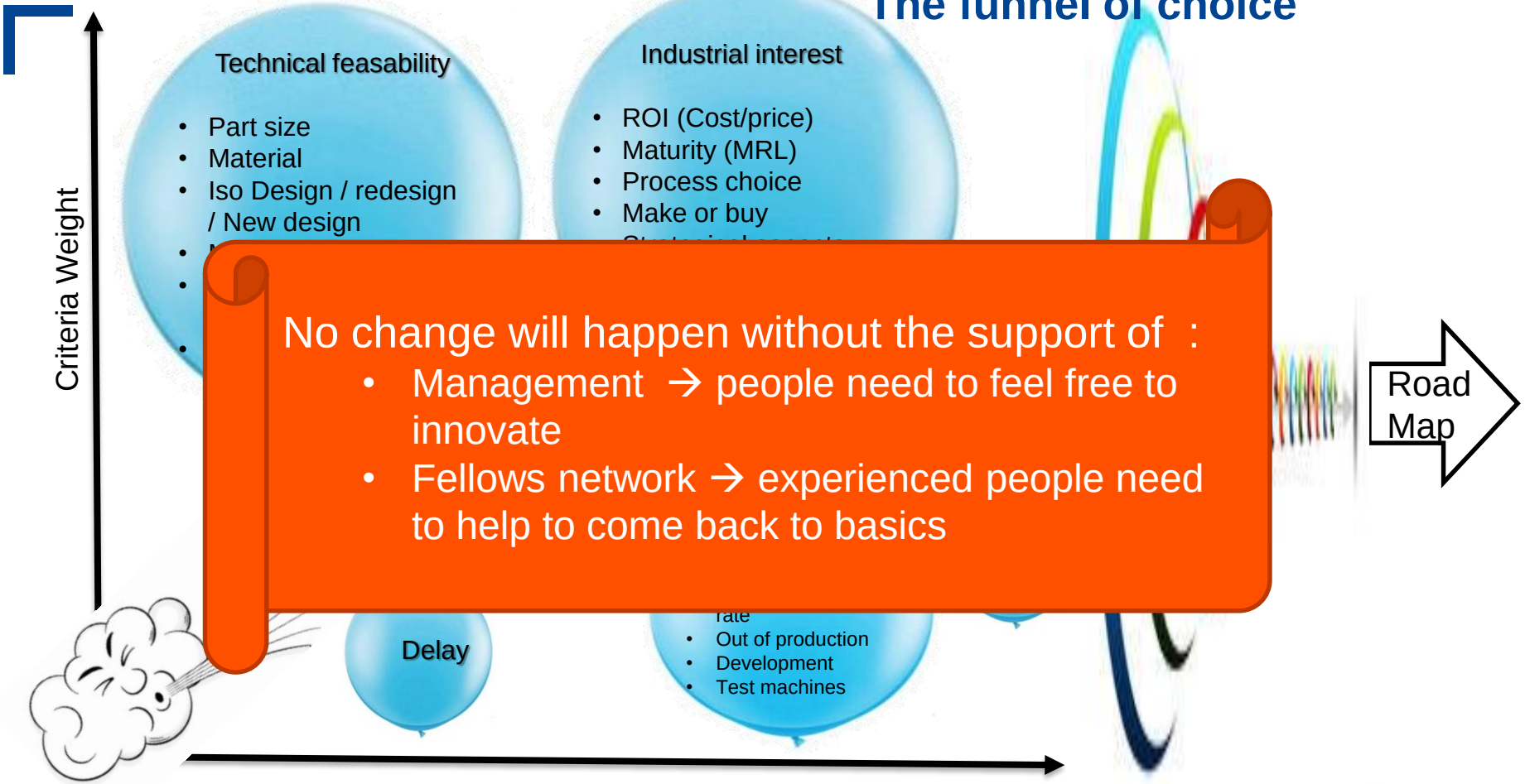
We need to start now with minimal design adaptations to support current objectives and prepare next challenges.

A program life

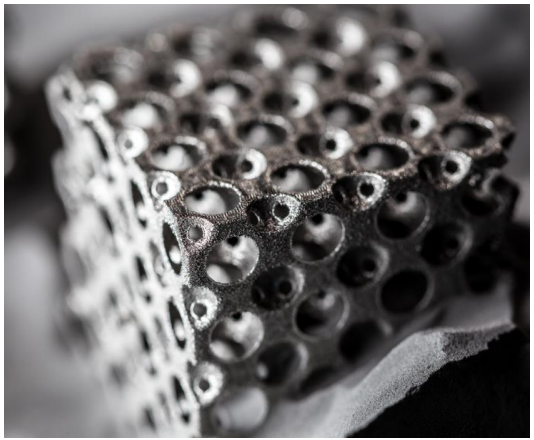


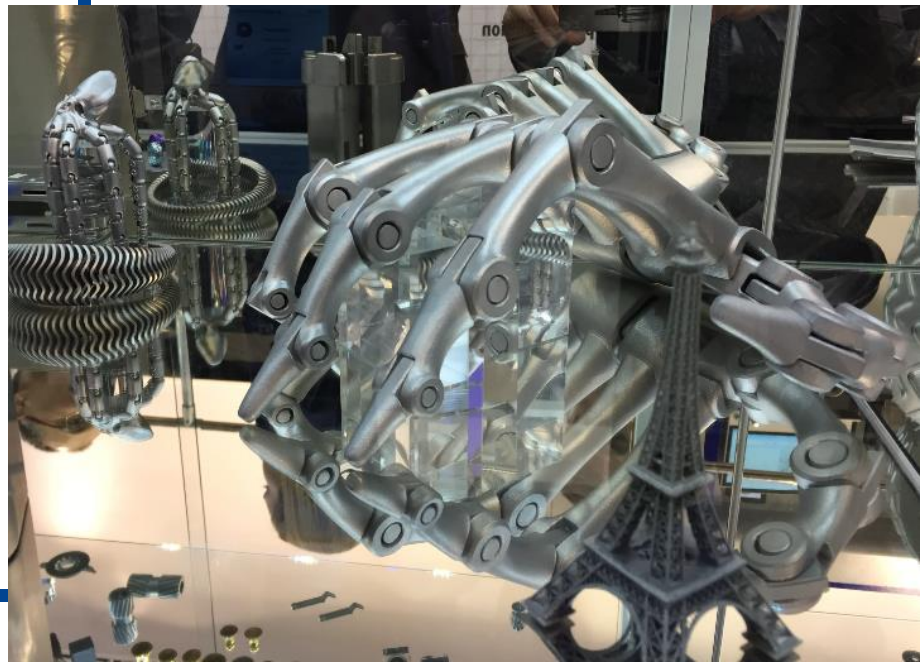
In aeronautic there are few opportunities to make real BIG changes. Technology needs to be ready when the decision has to be taken.

The funnel of choice



CONCLUSIONS





CONCLUSION

- Additive Manufacturing entered in the real life of Safran products : 4 parts certified to date.
- These technologies will be more and more part of the tools set available to complete classical manufacturing tools as they open :
  - New ways of optimizing and/or integrating functions,
  - New materials : chemistry, microstructure, meso structure, multimaterials, …
  - New system concepts, more integrated : fusion of AM and IoT
- **Cost, productivity, reliability** of the whole value chain are of first importance to enable AM use widening in Aerospace.
- To enlarge AM use and take all the best from these technologies, we need
  - To accelerate our understanding of AM processes
  - To support engineers to think out of the box

POWERED
BY TRUST

THANK YOU