# Clean Sky Additive Manufacturing research activities

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EASA European Aviation Safety Agency

**Additive Manufacturing Workshop**
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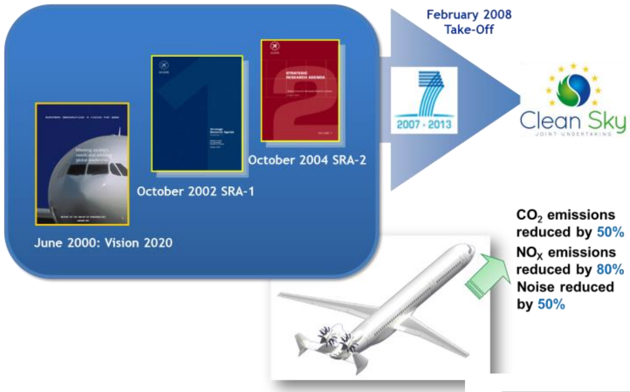
www.cleansky.eu www.easa.europa.eu

# AGENDA

- Introduction to Clean Sky Initiative; Integrated Technology Demonstrators
- Example of activities / projects concerning new manufacturing methods
- Other initiatives

# Clean Sky organization
# Integrated Technology Demonstrators



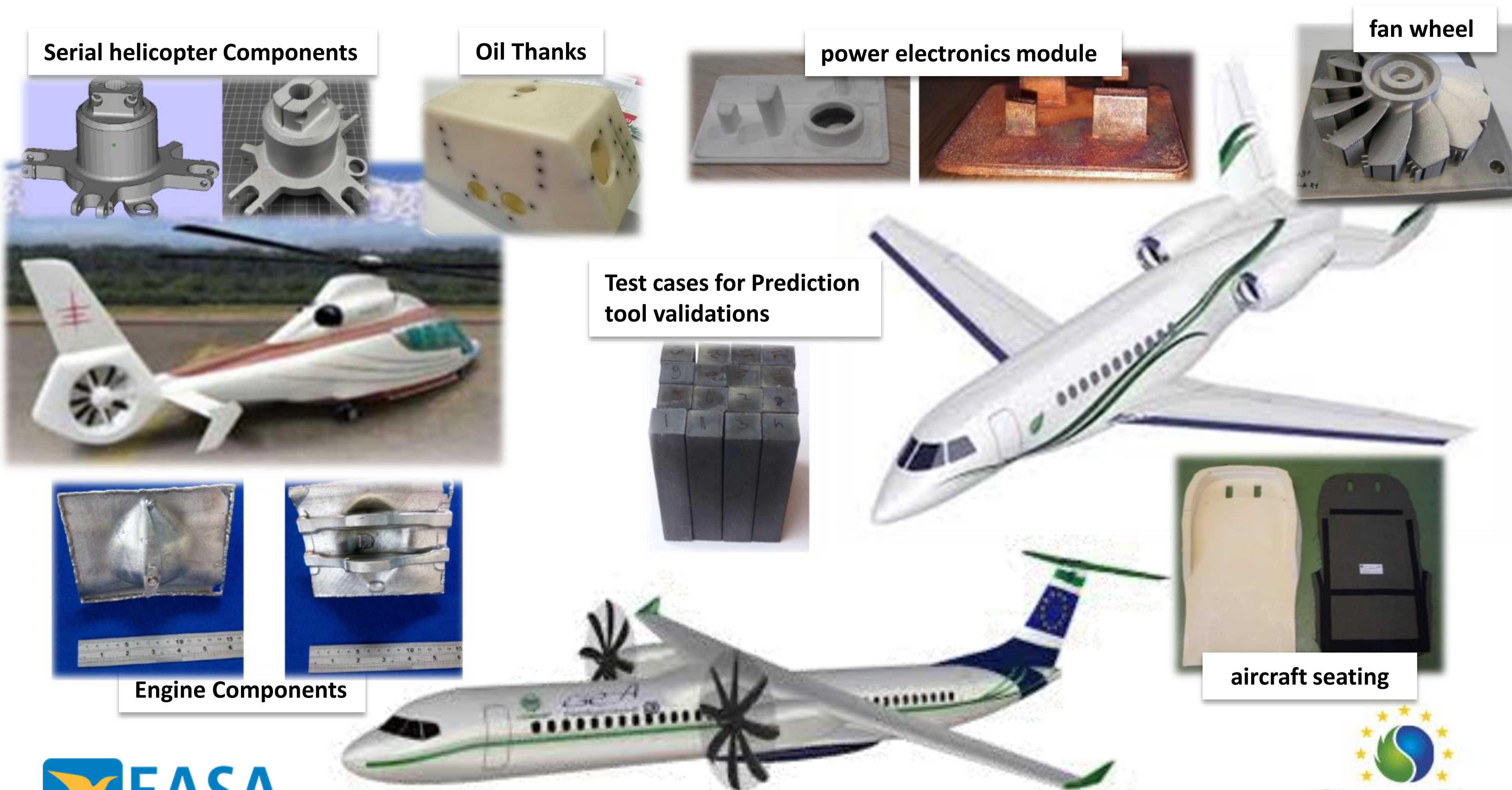

| | |
|---|---|
| **Smart Fixed Wing Aircraft** | |
| | Airbus (F, D, UK, E) |
| | SAAB (SE) |
| **Green Regional Aircraft** | |
| | Alenia Aeronautica (I) |
| | EADS CASA (E) |
| **Green Rotorcraft** | |
| | AgustaWestland (I, UK) |
| | Eurocopter (F, D) |
| **Sustainable and Green Engines** | |
| | Rolls-Royce (UK, D) |
| | Safran (F) |
| **Systems for Green Operation** | |
| | Thales (F) |
| | Liebherr (D) |
| **Ecodesign** | |
| | Dassault Aviation (F) |
| | Fraunhofer Gesellschaft (D) |

**Technology Evaluator**
Thales
DLR


EASA
European Aviation Safety Agency

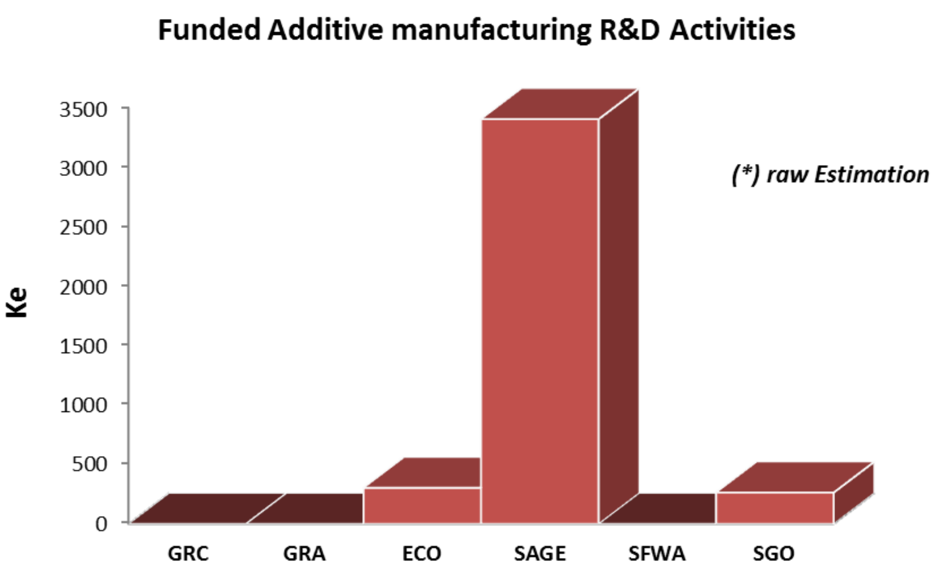
# Clean Sky Additive Manufacturing research activities

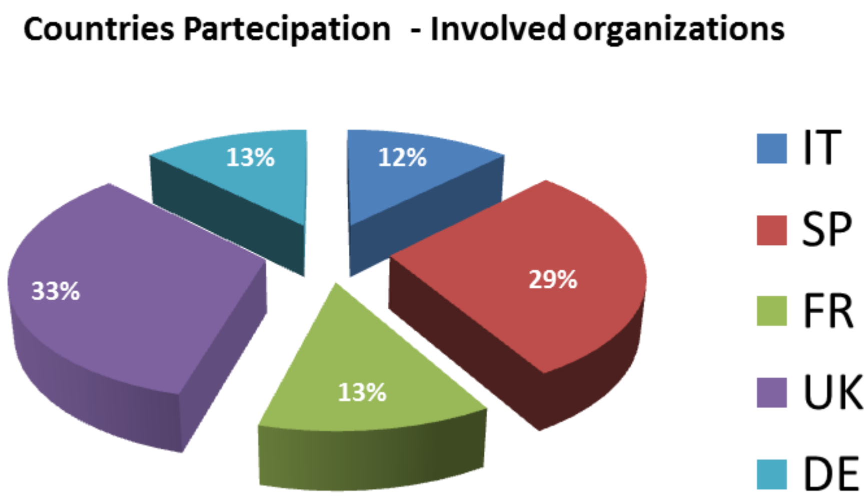
## Some examples of research fields funded within the CS1 framework



# Clean Sky Additive Manufacturing research activities

- More than 15 Clean Sky projects were fully dedicated to innovative manufacturing processes (like Additive manufacturing) in aircraft component manufacturing
- Projects ranged from basic research activities to industrial and complex applications




***24 Organizations***

Example of Projects performed by Partners

*Research* (low TRL)

# Clean Sky Additive Manufacturing research activities

Cfp : **JTI-CS-2012-02 - SAGE-04-019**

Project: **SIMCHAIN – 326020**

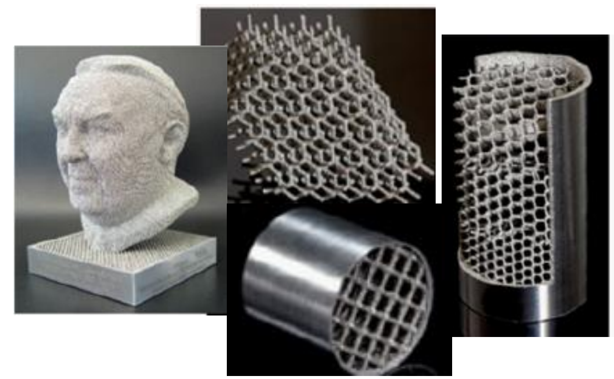
Basic Research

TITLE: Development of physically based simulation chain for microstructure evolution and resulting mechanical properties focused on *additive manufacturing processes*

Coordinator: **University of Bayreuth (UBT) – Germany**

Duration: **38 Months**

## Background



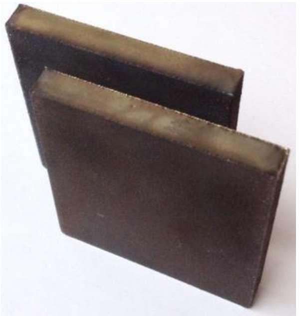
- Powder bed based additive manufacturing processes such like Selective Laser Melting (SLM) belong to the key technologies of the future allowing the production of complex shaped components from powder of high performance metallic alloys with nearly no waste.

- To optimize the process and the properties of the components, it is fundamental to identify reasonable process windows, ensuring part integrity and stable mechanical properties without giving up to much flexibility in the additive manufacturing process.

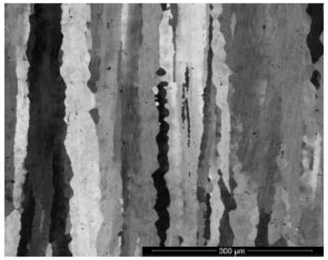
# Clean Sky Additive Manufacturing research activities

The aim of the project SIMCHAIN is to establish and to provide a full software set, which allows the prediction of resulting mechanical properties of materials produced by additive manufacturing processes (e.g. SEBM) as a function of the various sensitive process parameters.

- Several Specimens were built up with **selective electron beam melting (SEBM)** and were further machined to receive the final geometry for thermo-physical and mechanical testing.

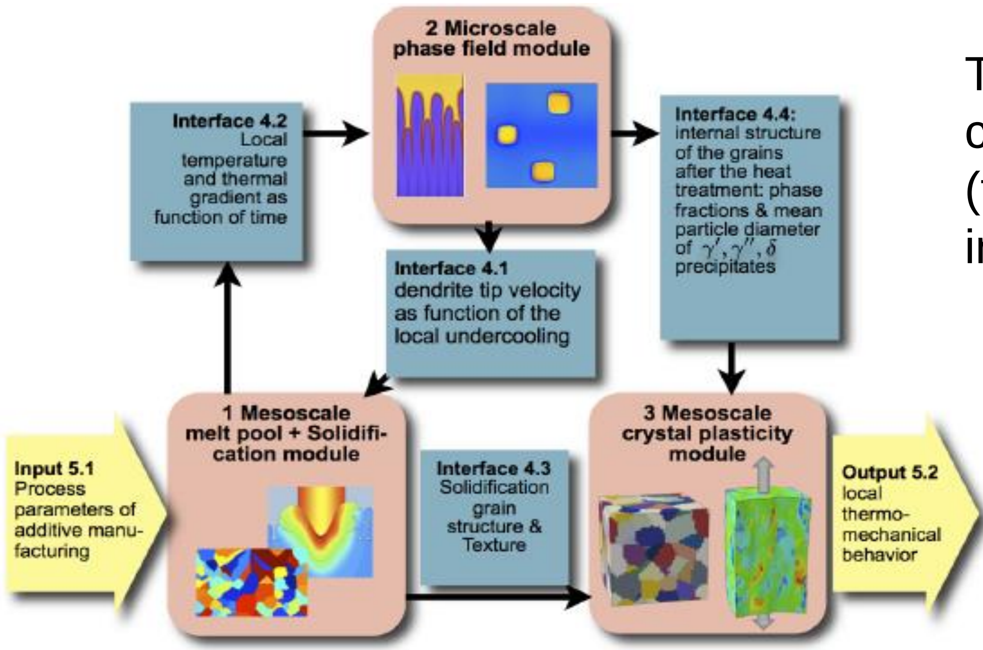


- Experimental tests have been performed to built a database about mechanical properties of tested specimens
  - ✓ Resonance Frequency and Damping Analyse
  - ✓ thermo-mechanical characterization (up to 600 Celsius degree)
  - ✓ Dynamic differential scanning calorimetry (heat capacity, thermal diffusivity, thermal length expansion)
  - ✓ Christallography



# Clean Sky Additive Manufacturing  research activities

A simulation chain that is able to predict local mechanical properties of SEBM additive manufactured parts using an **IN718 metal powders** as a function of various process parameters has been developed, as schemed:



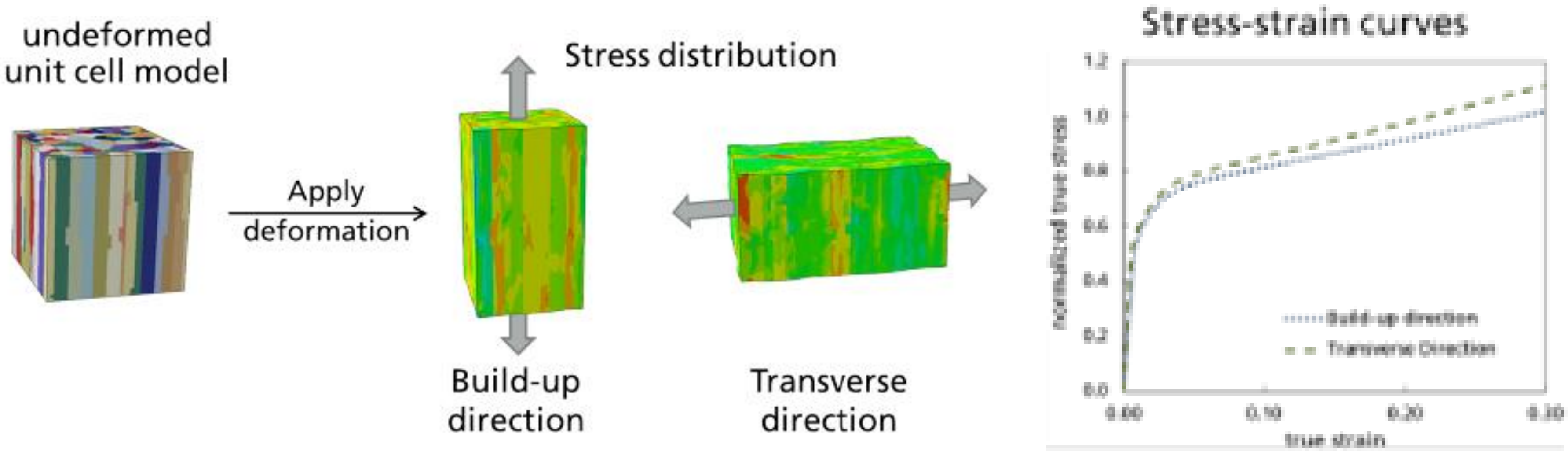

The developed numerical code is composed of the following main modules (to account for different parameters involved in the manufacturing process)

- Module 1 – Solidification module
- Module 2 – Microscale phase
- Module 3 – Crystal plasticity

Modules have been implemented in the code joining literature information and experimental tests on specimens.

# Clean Sky Additive Manufacturing research activities

- The developed simulation chain has been finally validated comparing experimental test results with numerical simulations.




- A very good agreement was found between numerical estimations and experimental tests providing evidence that prediction tools can be developed for the characterization of materials produced by the additive manufacturing process (e.g. Selective Electron Beam Melting - SEBM) as a function of the various sensitive process parameters.
- Prediction tool will be a key point for future design.

## Examples of Projects performed by Partners

*Industrial application*

# Clean Sky Additive Manufacturing research activities

Cfp : **JTI-CS-2012-02 - ECO-01-056**

Project: **Hi-StA-Part – 325931**

TITLE: Development and demonstration of Direct Manufacturing technology for High Strength Aluminium Alloys

Coordinator: **TWI Limited (UK)**

Duration: **26 Months**

**Industrial Application**

## Background

- Direct Manufacturing (DM) technology or Additive Manufacturing (AM) in the last ten years has demonstrated significant potential in the reduction in costs of aerospace components.
- These can be realised through improved design freedom (allowing light-weighting of parts), improved buy-to-fly ratios (lower raw material usage) and reduction of tooling cost followed by reducing the carbon footprint in manufacture and use of aircrafts.

The **Hi-StA-Part** project aimed to demonstrate that relevant Aircraft components and parts can be manufactured with a significant weight reduction according to the required mechanical properties for aerospace applications.

# Clean Sky Additive Manufacturing research activities

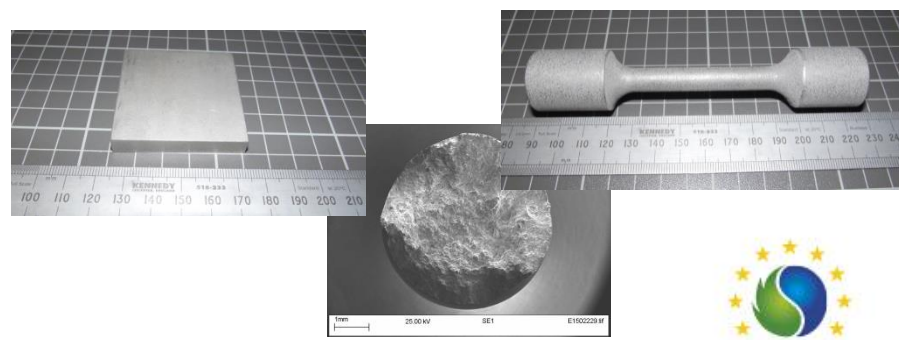
Aircraft parts are subject to unique loading and extreme environmental conditions during operation. Therefore metal alloys used for their construction must feature high stress and corrosion resistance qualities, exhibit low density and show ease of processing.

**SLM system with vacuum chamber (at TWI)**


Hi-StA-Part project used a material called **Scalmalloy** (developed by EADS APWORKS) to demonstrate high strength aluminium alloy compatible with A/C application

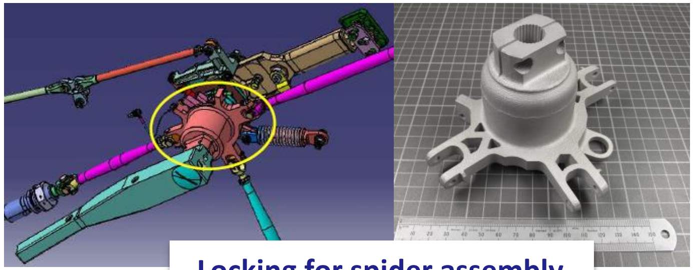
Several Specimens were built up with selective electron beam melting (SEBM) and were further machined to receive the final geometry for thermo-physical and mechanical testing.

- ✓ Fatigue testing
- ✓ Thermo-mechanical characterization
- ✓ Corrosion



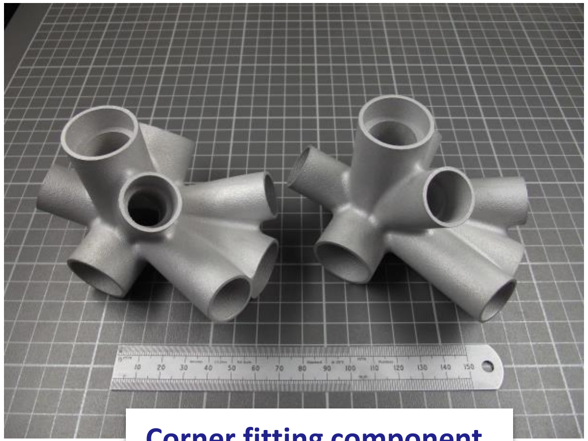
# Clean Sky Additive Manufacturing research activities

Two demonstrator components were chosen as final step of the project.
The first was the locking hub used in the aeroplane doors and second was corner fitting component used as an interior component for aeroplane.



Locking for spider assembly

- parts were produced with an EOS M280 machine with a 400W laser, with a layer thickness of 50µm.
- All parts were thermal treated ( HIP: 300°C - 350°C / 2000bar / 2-4h)
- All parts were removed of any support material from the build and were surface threated



Corner fitting component

***Important Remarks:*** *Dimensional checks showed that manufactured parts have a typical range of deviation of 0.250mm from the as built to the CAD model.*

## Conclusions

- Produced parts have a typical range of deviation of ±0.25mm from the as built to the CAD model. Meaning that the AM processing could be implemented as new process route in certain applications, only.
  Re-machining of some parts is necessary to remove some spots

- Tests on specimens highlighted that the selected material and process are fine from a mechanical, thermal fatigue and corrosion point of view.

- Based on the collected data, the proposed technology could have positive impact for both environmental and economic points of view:
  - *In an Airbus A380 aircraft where there are 14 exits doors (14 spider assembly Components), cost savings is 3,500 € approximately. Much higher cost saving can be achieved extending AM to other A/C components.*
  - *The overall environmental impact for manufacturing spider assembly components using SLM technology is 80 % less than the traditional machining processes for same product. This is mainly due to the reduction of the resources required for the manufacturing as well as for a reduction of waste.*

# Clean Sky Additive Manufacturing research activities

Cfp : **JTI-CS-2013-1-ECO-01-066**

Project: **TIFAN – 620093**

TITLE: Manufacturing by DMLS and machining of a titanium fan wheel. Comparison with casting process

Coordinator: **LORTEK (SP)**

Duration: **18 Months**

Challenging Application

**Reference fan wheel is installed in different aircraft types, for example, two units are placed on Airbus A321 NG.**

## Background

To match thermal, stress and fatigue requirements, fan wheels are currently manufactured by two processes:

- stainless steel fan wheel manufactured by bar machining,
- titanium alloy TA6V fan wheel manufactured by bar machining

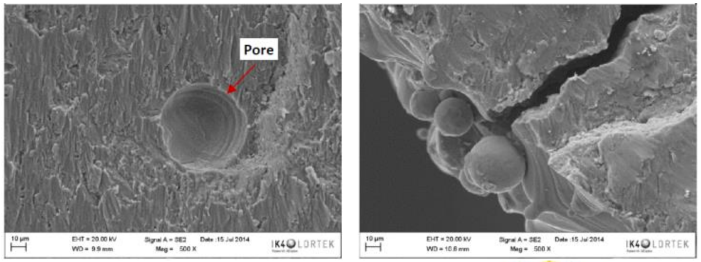
The aim of the TIFAN project was to develop alternative "green" manufacturing processes for a **titanium fan TA6Al4V wheel** by Selective Laser Melting (SLM).

# Clean Sky Additive Manufacturing research activities

The project addressed the comparison between optimized SLM and conventional manufacturing process (bar machining) in terms of mechanical, fatigue and corrosion performance as well as environmental impact and manufacturing cost.

The main factors providing manufacturing cost reduction, weight reduction and mechanical performance improvement were also investigated

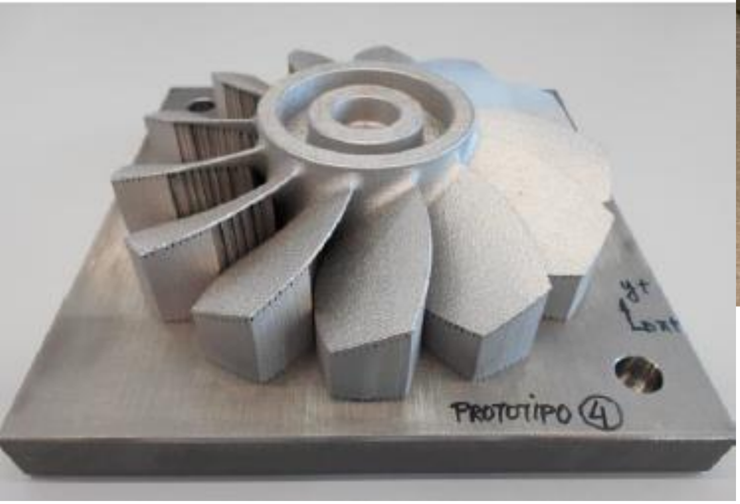
- In order to study the mechanical properties of Ti6Al4V produced by Selective Laser Melting (SLM) process samples were manufactured.
- Samples showed uniform and good results in terms of tensile stress.
- Samples showed high scattering concerning fatigue and some samples detected very poor fatigue results.
- Metallographically analyses showed that this was due to the presence of internal Pores

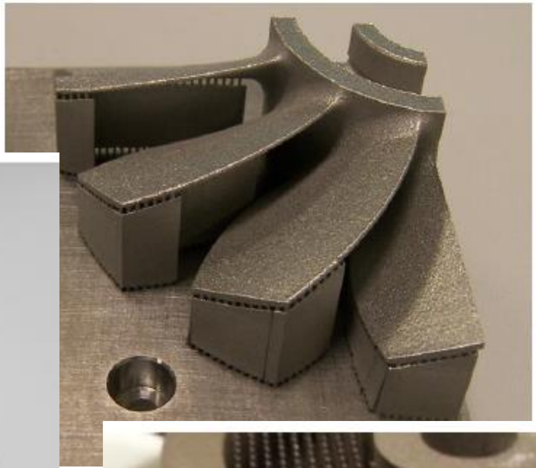


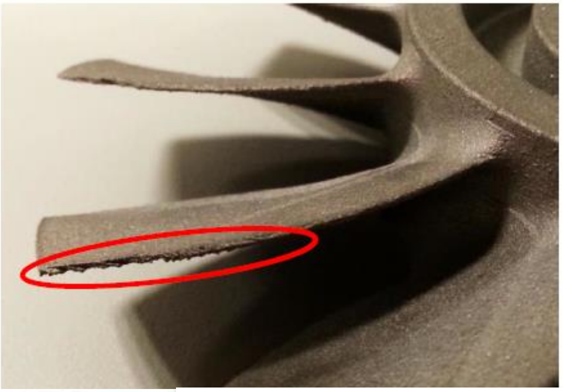
# Clean Sky Additive Manufacturing research activities

In order to reach high performances, it was demonstrated that it is compulsory to apply thermal, machining and surface treatments after SLM manufacturing.

13 fan wheel prototypes have been manufactured combining different manufacturing processes and thermal treatments in order to find optimal production setting.





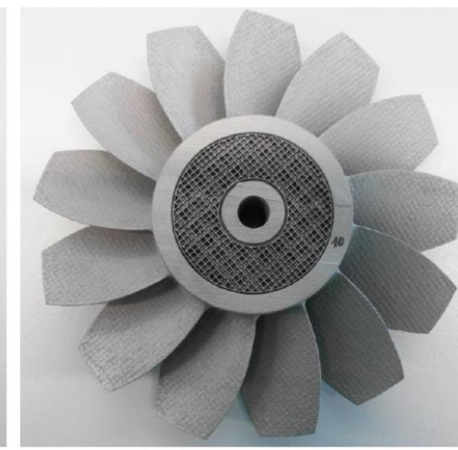
**Detected Defects in some prototypes**

## Conclusions

Optimal manufacturing process for the manufacturing of **titanium alloy fan wheel was identified and the final demonstrator was manufactured** assuring optimal behaviour in terms of stress concentrations, fatigue life, corrosion and desired vibration mode frequencies

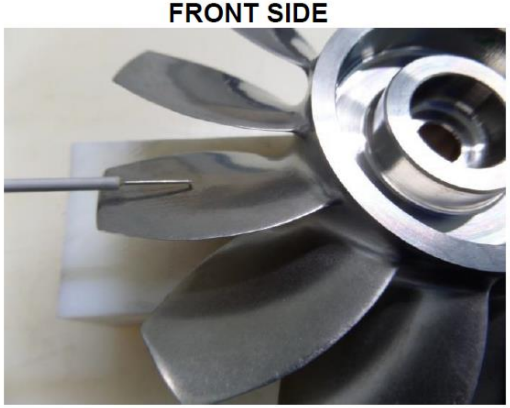
FRONT SIDE

REAR SIDE



**Thermal,**
**Machining**
**Surface treatments**

FRONT SIDE



REAR SIDE

# Clean Sky Additive Manufacturing research activities



**Additive Manufacturing Demonstrator showed at Le Bourget (15 - 21 June 2015)**

# Other initiatives

## Metal Additive Manufacturing @ POLIMI

AddMe.Lab

Lab for Additive Manufacturing @ Department of Mechanical Engineering of Politecnico di Milano

4 research groups:

- manufacturing, materials, design, mechanical testing

5 companies:

- BLM, Titalia, Sapio, Maspero, Marposs

Clean Sky
JOINT UNDERTAKING

# Other initiatives

Our networks of excellence

**IDEA League** A focused network of leading European universities of science and technology


TU Delft – Delft University of Technology

ETH Zürich

RWTH AACHEN UNIVERSITY

CHALMERS UNIVERSITY OF TECHNOLOGY

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Technische Universität Berlin and
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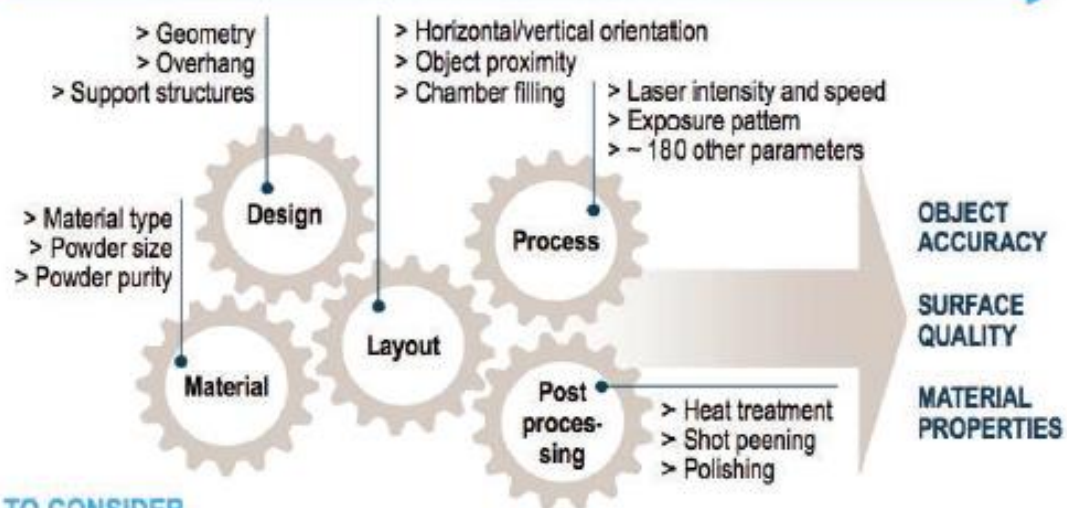
Clean Sky JOINT UNDERTAKING

# Other initiatives

## A multidisciplinary challenge

### Complexity of AM production process

**PRODUCTION PARAMETERS AND CHALLENGES** (example)




**TO CONSIDER**

- Tension and curling
- Heat dissipation
- Stair-stepping effect
- Anisotropy in z-axis
- Volume contraction
- Micro melting[1)]

**IMPLICATIONS**

- As of today, there is no complete set of design, layout, material, machine and process rules
- Practitioners need to tailor the production process to each specific object
- Adaptations, such as the use of new material, require up to one year of development time
- More experience needed in the next 5-10 years before new objects can be made with less effort
- Simulation models will shorten development times in the future

1) Change in material properties

Source: Expert interviews; Roland Berger

**Thank you**
**for your attention**

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**www.cleansky.eu**