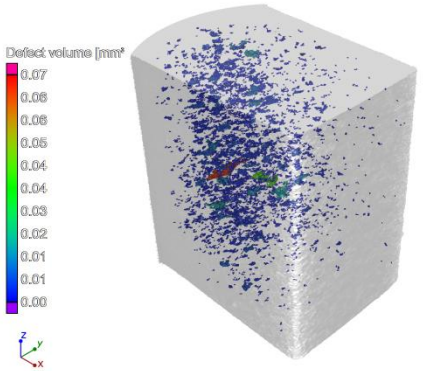
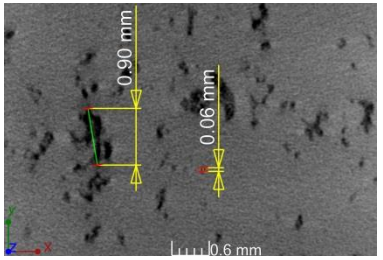


NDT for Additive Manufactured (AM) / 3D-Printed Parts

What does this mean for MRO?

A4A NDT Workshop 2016, San Diego, US



Content

- Introduction to AM
- AM Approach for Service
- Quality & Inspection Aspects
  - Powder Quality
  - Dimensional Measurements
  - NDT Techniques
- Conclusion

Introduction to Additive Manufacturing (AM) for Metals

What is AM?

Wikipedia:

- A**dditive manufacturing** (**AM**), refers to processes used to synthesize a three-dimensional object in which successive layers of material are formed under computer control to create an object.

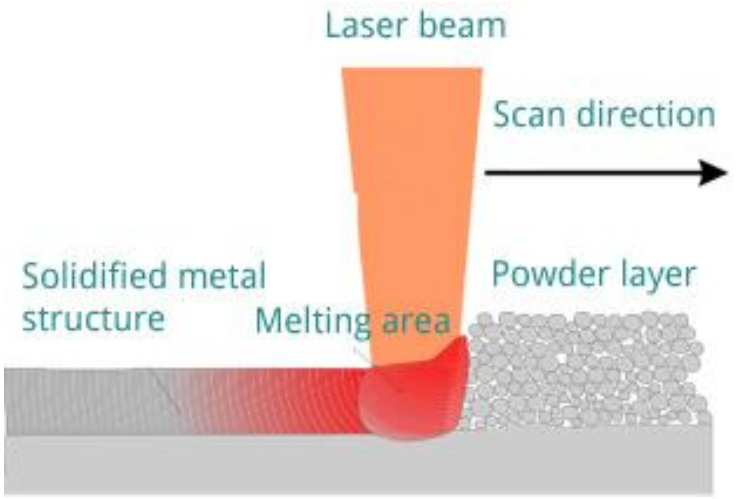
- Additive Manufacturing = Industrial 3-D Printing

- AM for metals is a welding/sintering process

- Several different processes for metals are existing, e.g.
  - Powder Bed: Selective Laser Melting (SLM)
  - Electron Beam Melting (EBM)

Selective Laser Melting (SLM)

- Used for Titanium and Aluminum Parts
- Most promising technology for Aerospace
- Mainly used in Aerospace and Orthopedics
- Layers between 0,020 and 0,100 mm are produced



Source: IQ-Evalution

Post Processing

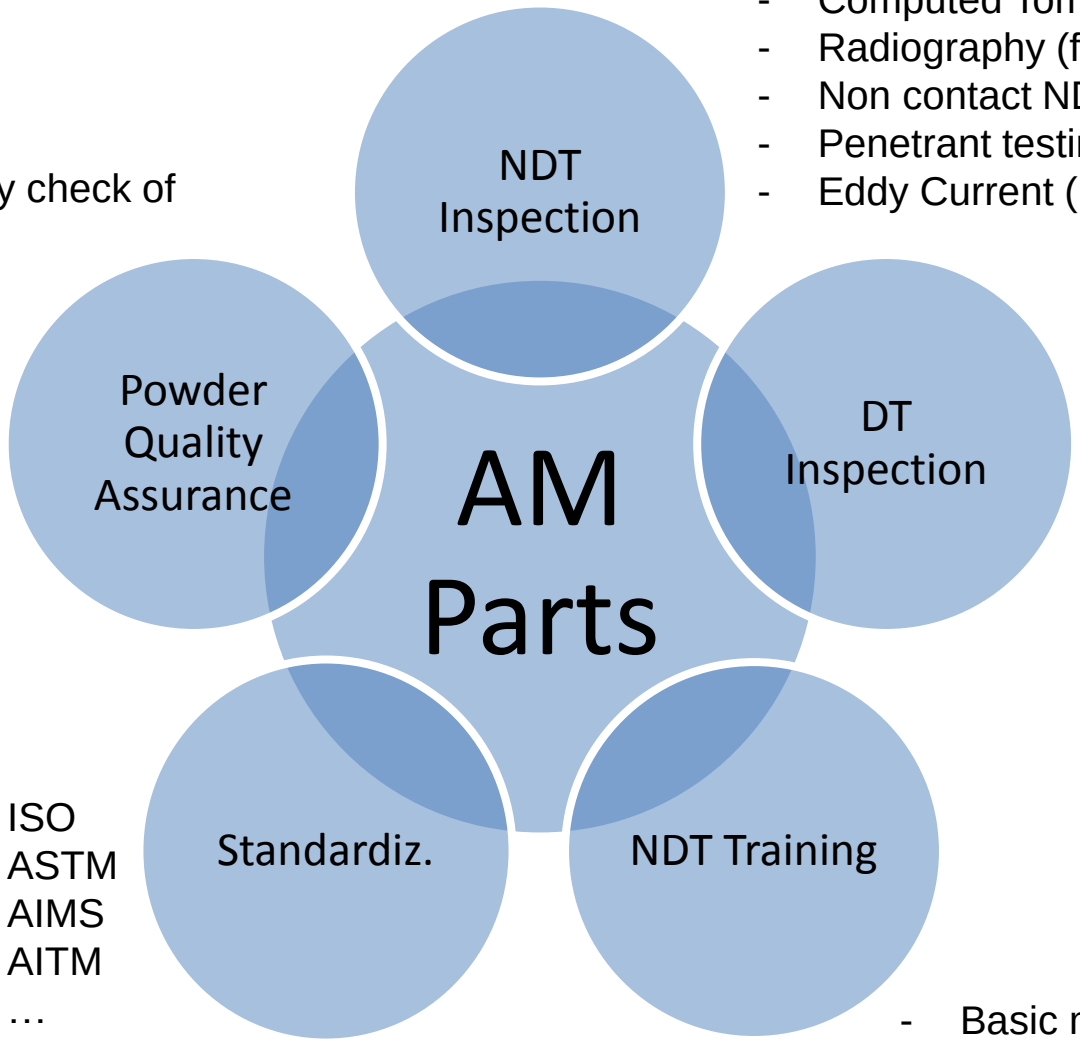
- Surface of AM parts very rough
  - Post treatment partial necessary, especially in case of need for inspection (e.g. Penetrant Testing)
  - Mechanical or chemical milling might be applied

- For high load parts a Hot Isostatic Pressing (HIP) is mandatory.
  - HIP is used to eliminate pores and remove defects, i.e. nitrides, oxides and carbides and to dramatically increase the material properties.

Quality related Topics

- Computed Tomography (CT)
- Radiography (film and digital) (RT)
- Non contact NDE metrology
- Penetrant testing (PT)
- Eddy Current (ET)

- Pre-delivery check of powder



- Tensile tests
- Compression tests
- Shear tests
- Metallography
- Hardness tests
- Fatigue tests
- Fracture toughness tests
- …

- ISO
- ASTM
- AIMS
- AITM
- …

- Basic method trainings
- Special application Trainings

AM Approach for Service

Justification

Manufacturing

- Implementation of AM in Manufacturing ongoing
- First Titanium Parts (Class 2.3 – non fatigue critical) approved by EASA (Airbus A400M)
- Future Focus on Class 1 and 2.1 parts (fatigue critical)

Service

- Need for availability of spare parts
  = production in-situ = reduce down-time
- Special parts for repairs
  = production in-situ = improve repair solutions

Expected Benefits for OEM / MRO

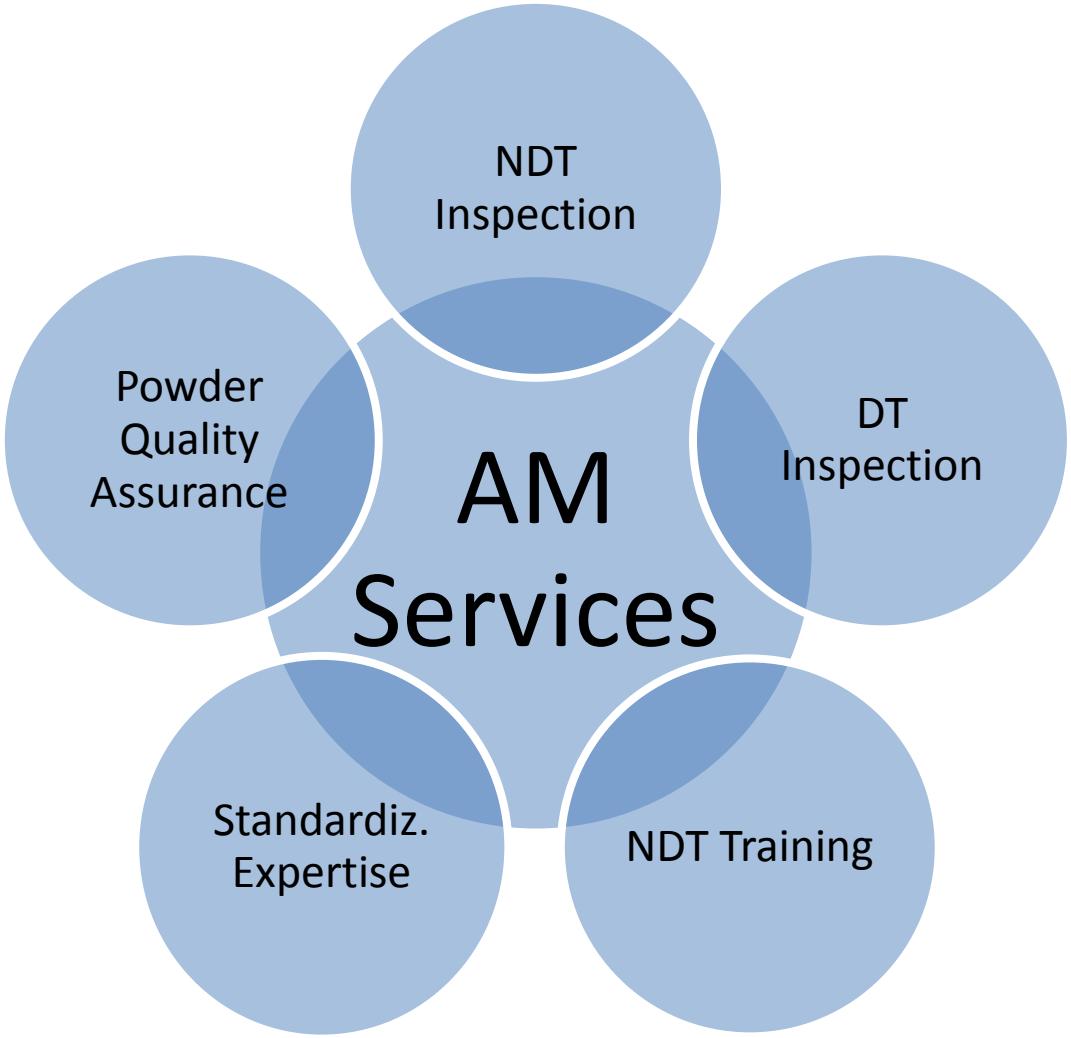
- Reduction of Warehousing costs by production on demand
- Complex parts can be manufactured at nearly no extra costs
- Quicker than several conventional manufacturing processes
- Avoid long lasting AOG

Challenges (Quality related)

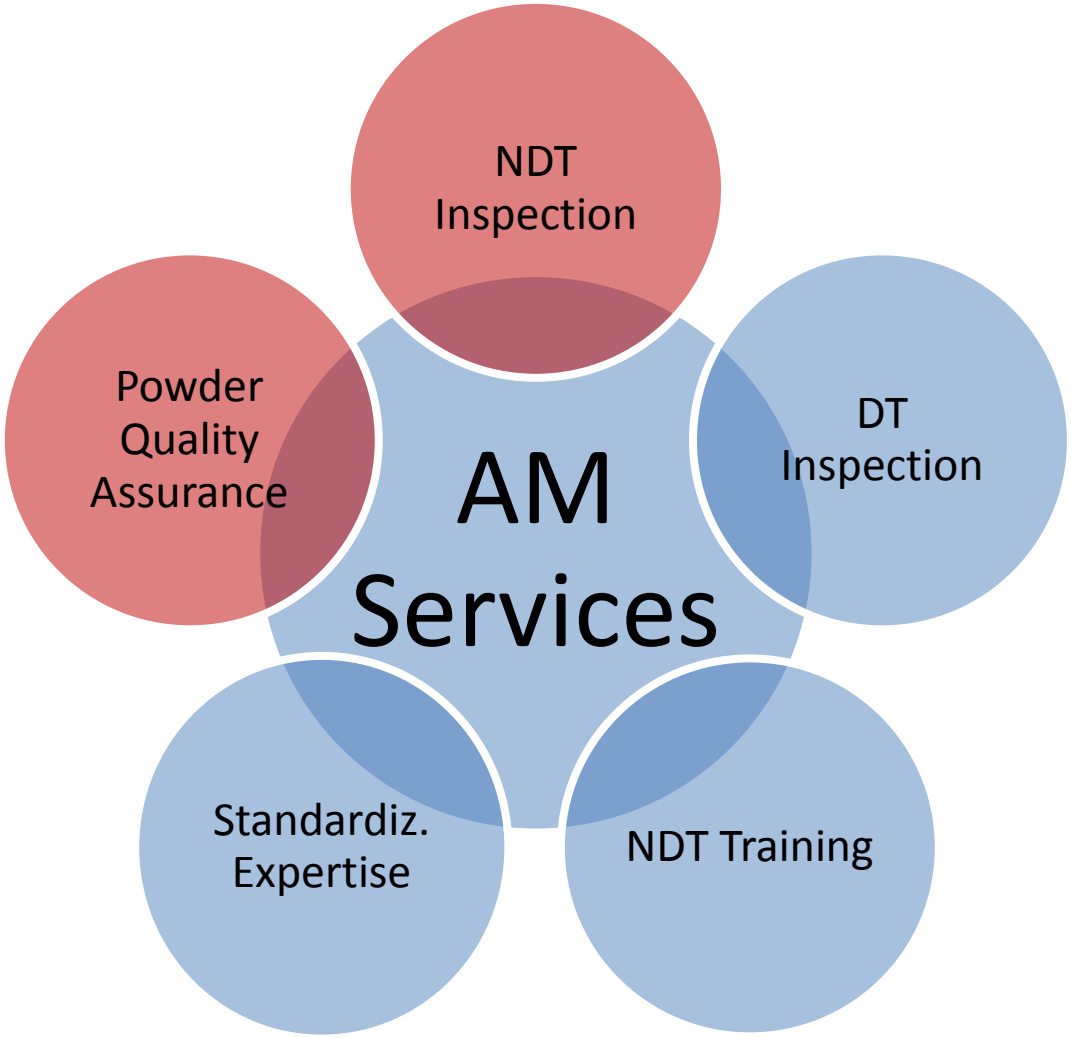
- Ensure quality of the powder during the printing process
- Having metal printing process under control
- Different materials can not be printed on one machines (today status)
- Dimensional measurement of complex parts to be done
- NDT technologies & tools to be available
- Inspectors trained to perform NDT on AM parts

Quality & Inspection Aspects

Quality and Inspection Aspects



Quality and Inspection Aspects



Powder Quality Assurance

Challenges

- AM process require high quality of powder
  - No contamination
  - Nearly no moisture
  - Size of powder particles
  - Shape of the powder particles
- No mix of powder charges
- Closed circuit has to be ensured
- Re-use of remaining powder

Dimensional Measurement

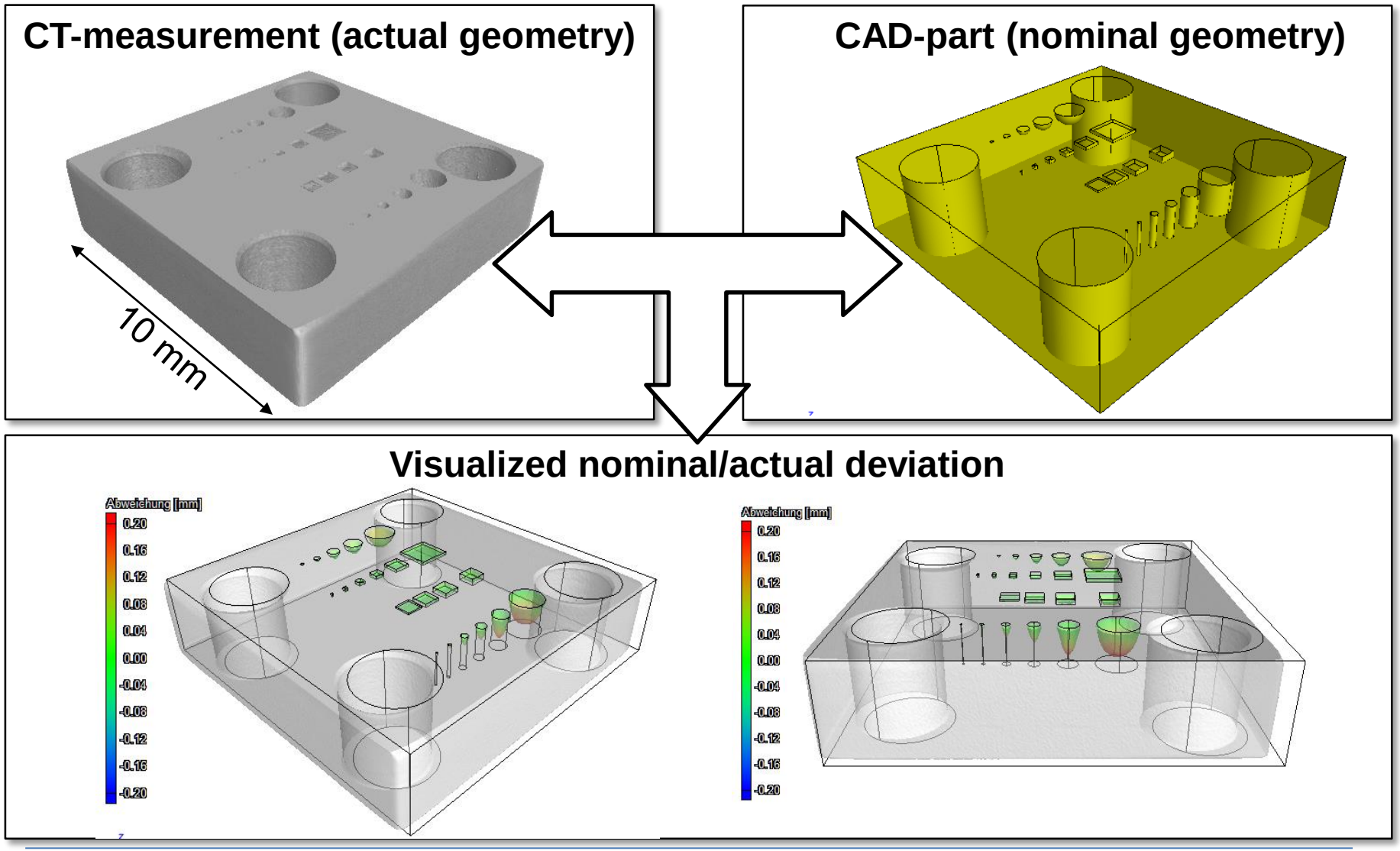
Dimensional Measurement

Usually all parts have to be measured, but for AM parts it is even more of relevance:

- Printing process could lead to unexpected deformation caused by the melting process
- Removing of the supporting structure could lead to unexpected deformation
  (usually taken into account during the design)
- Tolernaces of printing process today not as accurate as e.g milling

Example: Measurement with CT

- Nominal/actual comparison



Inspection Methods for AM Parts

Potential NDT Technologies

Main, currently envisaged NDT methods:

- Visual Testing (VT)
- Computed Tomography (CT)
- Digital X-Ray / Non-Film (RT-NF)
- Penetrant Testing (PT)

Additional, potential technologies

- Eddy Current (ET)
- Infrared Thermography (IRT)
- Leak Testing for complex structures (LT)
- Pressure Testing
- …….and more to come

Starting point: NDT applied as for castings

Most Promissing Technology - CT

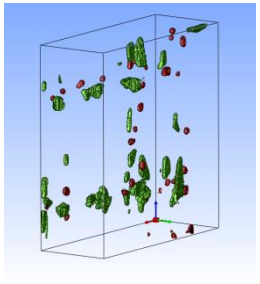
Technical data

Voltage	< 225 kV
Current	< 1000 µA
Focal spot	> 2 µm
Voxel size	> 2 µm

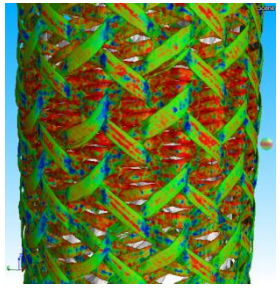
→ FlyBy acquisition (duration ~ 15 minutes)
→ Dual Energy CT

Some quantitative characterization methods
(depending on the material)

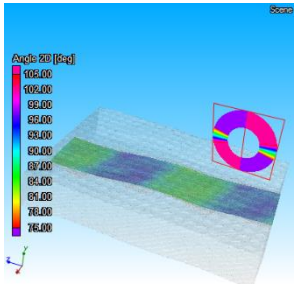
Porosity



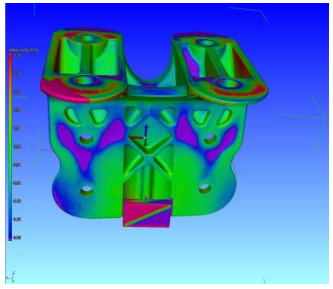
Structure



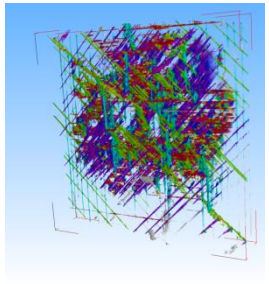
Undulation



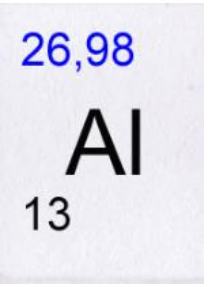
Shape



Damage

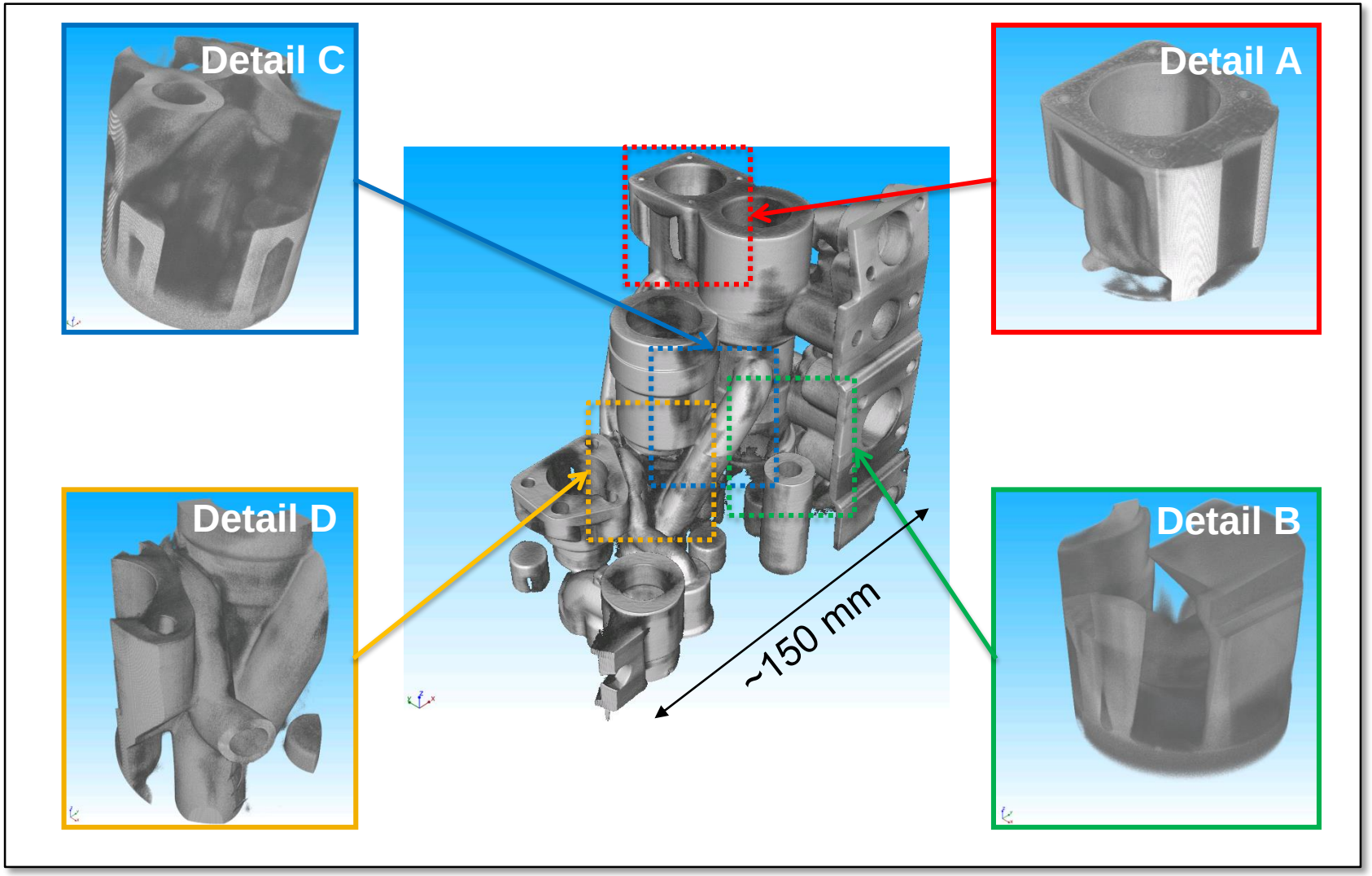


Material



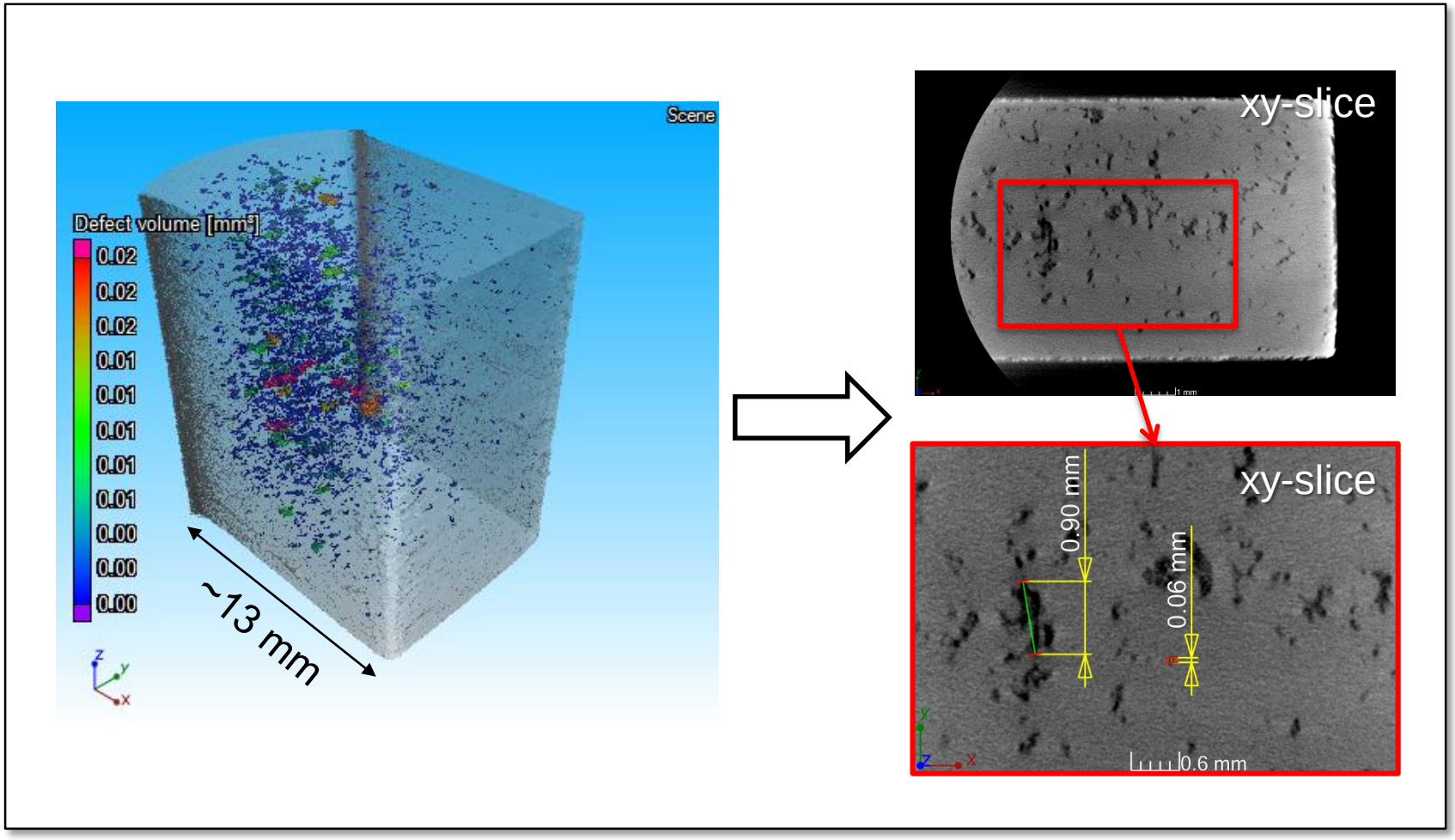
AM-Part NDT/CT Inspection

- Overview- and detail measurements



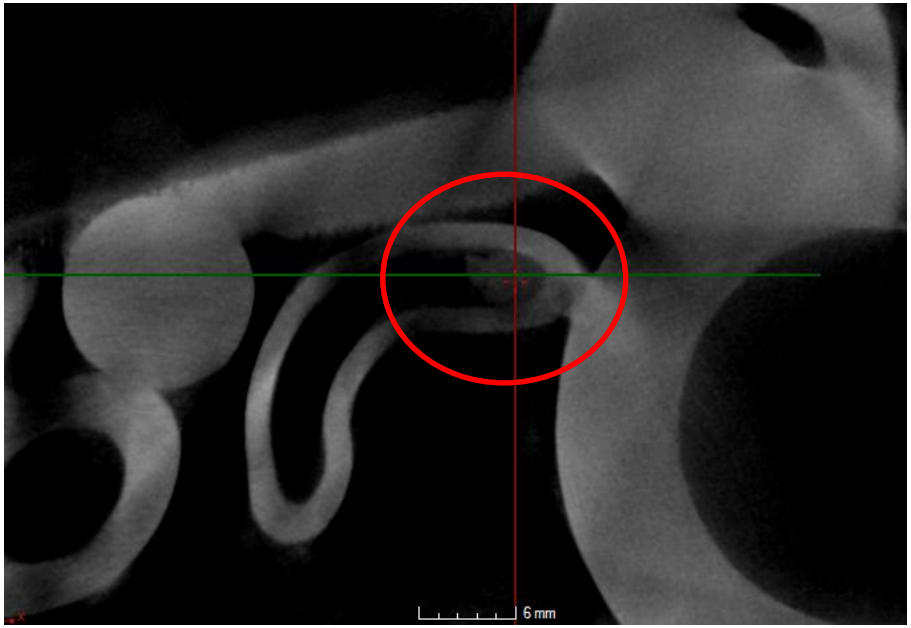
AM-Part NDT/CT Inspection

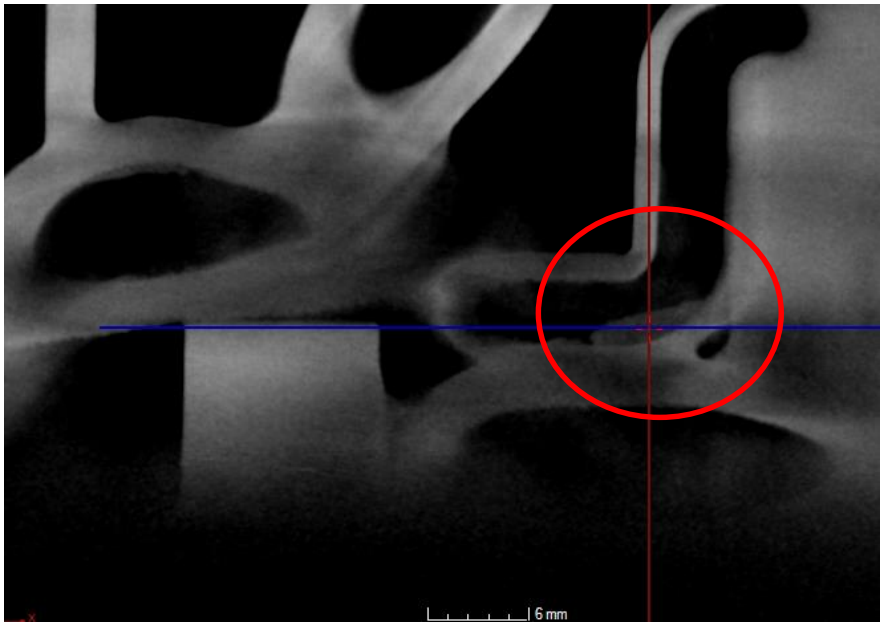
Porosity determination



AM-Part NDT/CT Inspection

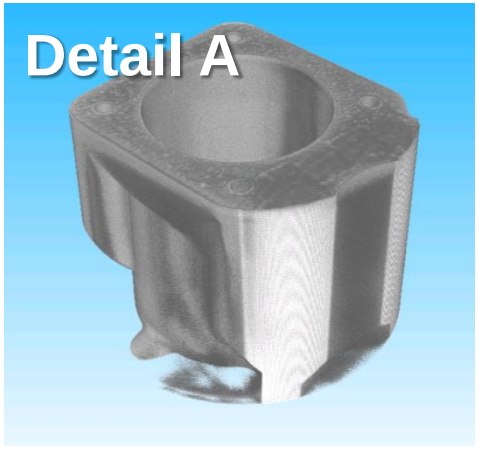
- Powder residues

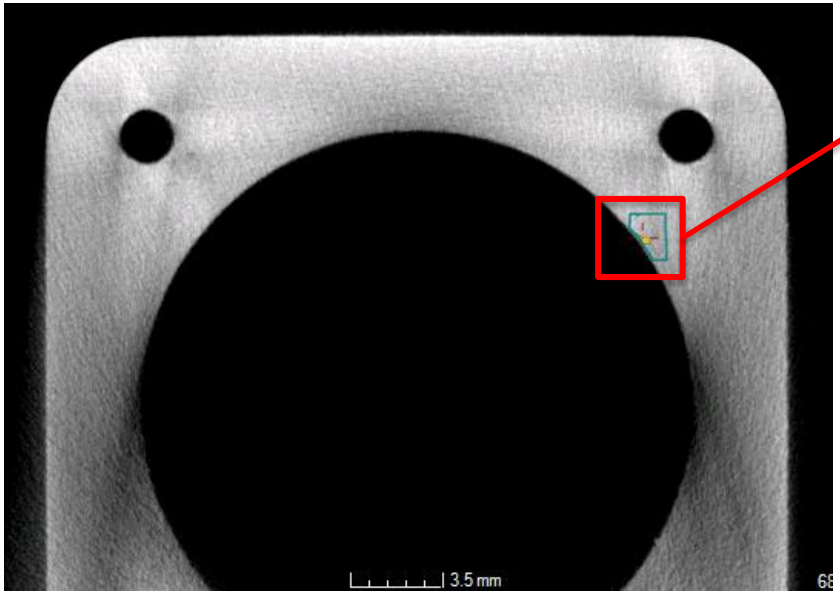


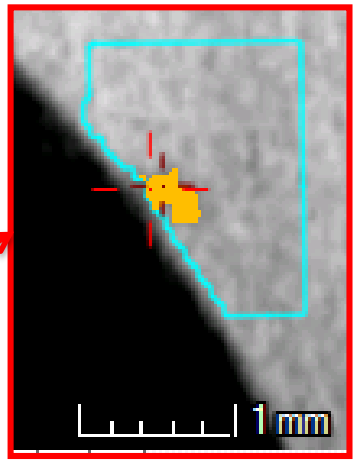


AM-Part NDT/CT Inspection

- Analysis of pores using detail measurements



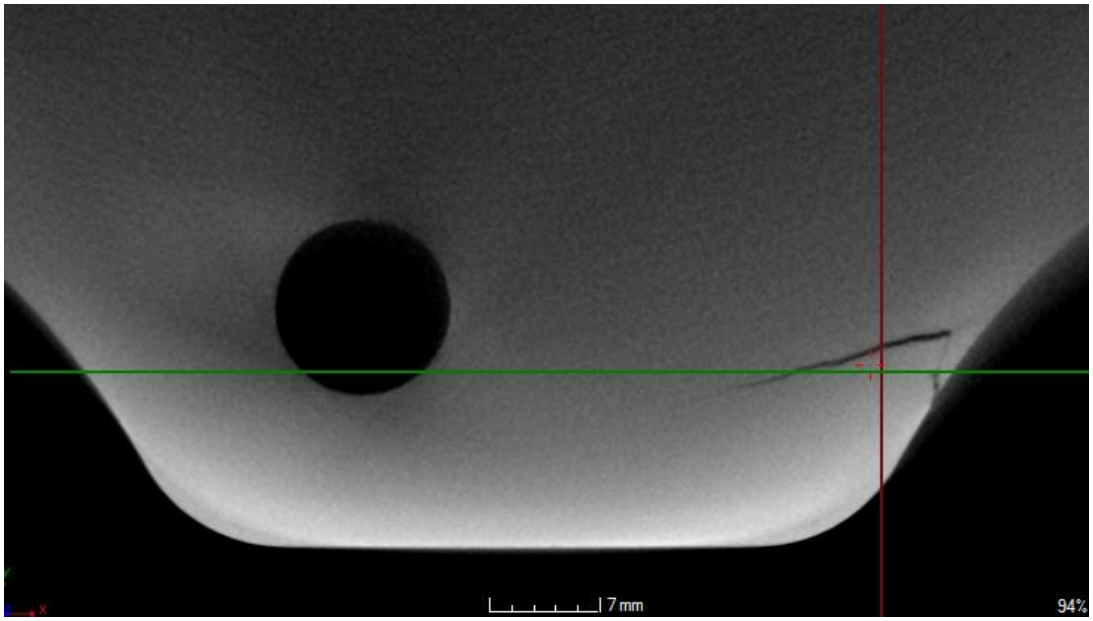




Diameter [mm]	Volume [mm³]	Voxel	Surface [mm²]	SizeX [mm]	SizeY [mm]	SizeZ [mm]	PX [mm²]	PY [mm²]	PZ [mm²]
censored									

AM-Part NDT/CT Inspection

- Crack analysis



Digital X-Ray

Digital / Non-Film X-Ray

- Standard Technique for castings and other parts

Source: GE

- Complete X-Ray Systems for automated post-printing inspection under development

- Software for automated X-Ray image analysis under development within Airbus Group (ULTIS)

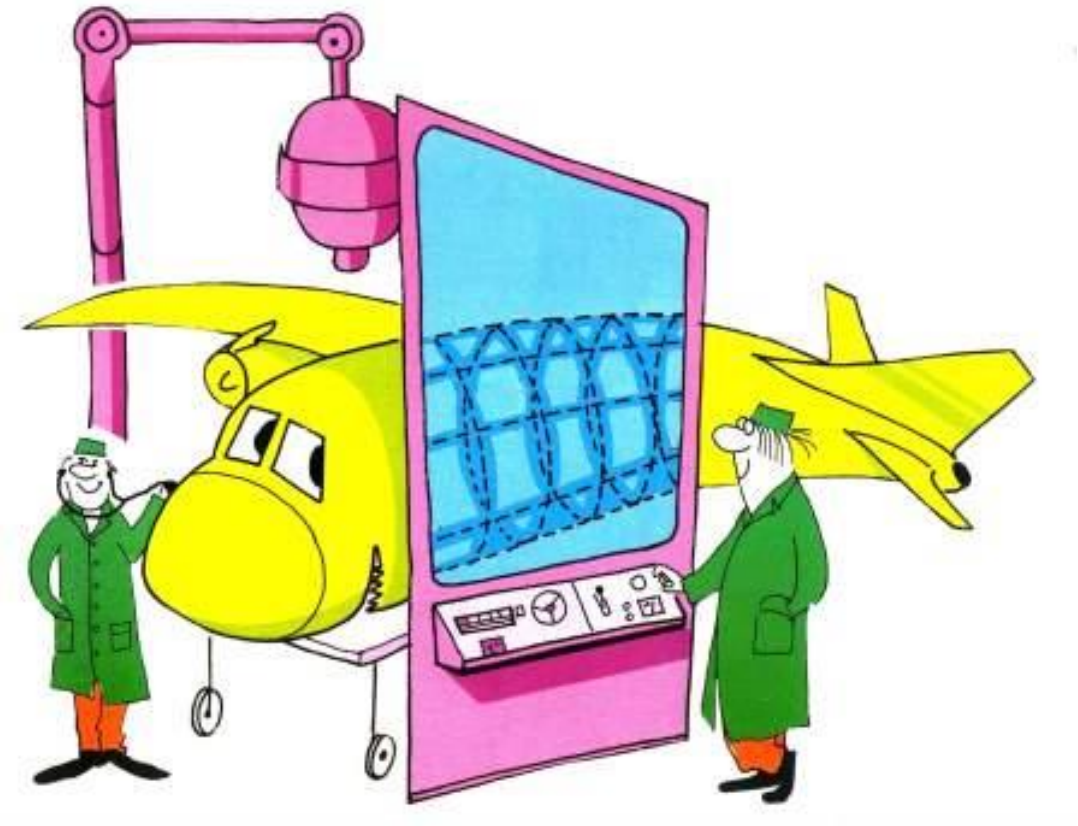

Consultancy
Engineering
Products & Tools
Product Development
Inspections & Testing
Training
TESTIA
AN AIRBUS GROUP COMPANY

Conclusion

Conclusion

- AM could revolutionize spare part manufacturing & availability
- Challenges (Quality related)
  - Complex parts difficult to inspect
  - Powder quality essential
  - Capabilities for NDT of printed parts
- OEM to prepare basic requirements and standards
- Opportunities for service companies (print & inspect)

NDT – the view under the skin !



Thank you very much for your attention!

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